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FIRST SERIES

OF

RAILWAY PRACTICE:

A Collection

OF

WORKING PLANS AND PRACTICAL DETAILS OF CONSTRUCTION

IN THE

PUBLIC WORKS

OF THE MOST

CELEBRATED ENGINEERS:

COMPRISING

ROADS, TRAMROADS, AND RAILROADS;
BRIDGES, AQUEDUCTS, VIADUCTS, WHARFS, WAREHOUSES, ROOFS, AND SHEDS;
CANALS, LOCKS, SLUICES, & THE VARIOUS WORKS ON RIVERS, STREAMS, &c.;
HARBOURS, DOCKS, PIERS AND JETTIES, TUNNELS, CUTTINGS AND EMBANKMENTS;
THE SEVERAL WORKS CONNECTED WITH
THE DRAINAGE OF MARSHES, MARINE SANDS, AND THE IRRIGATION OF LAND;
WATER-WORKS, GAS-WORKS, WATER-WHEELS, MILLS, ENGINES,
&c. &c.

BY

S. C. BREES, C.E.

LATE PRINCIPAL ENGINEER AND SURVEYOR TO THE NEW ZEALAND COMPANY,
FROM THE YEAR 1842 TO 1845.

Third Edition.

WITH ADDITIONAL EXAMPLES.

LONDON:
JOHN WILLIAMS AND CO.
LIBRARY OF ARTS, 193, STRAND.
1847.

PREFACE

TO

THE FIRST EDITION.

In presenting to the public the first volume of "Railway Practice," the author begs leave respectfully to explain the general intention and purpose of the publication.

It has long been his conviction that a work of this nature was required by practical and professional men, and that it would at all times prove acceptable to the public generally, yet more especially at the present moment, while railroads are the all-engrossing topic of conversation and discussion, and the subject of investigation the most acute and searching.

This early impression on the author's mind was confirmed by the opinion of gentlemen the best qualified to decide on such a question, and it became conviction when he was assured by his intelligent publisher, "that inquiries after such works were frequent, and the demand for information connected with them urgent." Satisfied, therefore, as to the paucity of such information, and the consequent value of any particulars descriptive of the *minutiæ* of this most important branch of engineering, he could not hesitate as to the propriety of producing his "Railway Practice," to which he now solicits the favourable notice of the reader.

The present volume has few pretensions as a work of art. The endeavour of the writer having been to render the whole plain and easy of comprehension, it

became his duty to avoid the expense of fine engravings, as unnecessary to the purpose in view; and it is in this plain and practical light that he would have his work considered and reviewed. The working plans are effectively portrayed, and the details and descriptions fully illustrated. A clear arrangement and appropriate distribution of subjects, strict adherence to correct drawing, and simple explanatory effect, are all that he has attempted, as author or artist, beyond a due regard to contrast in the selection of the works here represented and illustrated.

The whole of the plates are made to resemble actual drawings, from which indeed, when tinted, they will hardly be distinguishable; and it is presumed, that this easy and familiar effect will supply a *desideratum* to the profession, by whom the smaller engravings on engineering subjects are objected to for their severe dryness, extreme intricacy, and generally uninteresting appearance.

The series of designs for railway works are respectfully submitted to the attention of the profession, not that they are by any means considered as models of perfection. They are a collection of rough sketches, and of original ideas, of as much diversity of style and variety in plan as is perhaps practicable. Full latitude has been allowed to the pencil in these views; a hasty sketch frequently maintaining more of the original spirit in the form of composition, than when the idea is conveyed by a more elaborate process; seeing, that in the former case, something is left for the imagination to complete.

The author hopes to escape the charge of presumption, if venturing to assert, that in this respect a much wider field is open than is generally recognised. Notwithstanding the temptation, however, he has devoted but a few sheets to this portion of the work, being aware that examples from the extensive railways now progressing will prove more useful. Should the present volume, after a careful perusal, supply a few hints and suggestions, it will have equalled the anticipations and fulfilled the intentions of the writer.

The author of "Railway Practice" cannot conclude this brief Preface, without earnestly expressing his warm acknowledgments to the several gentlemen, engineers to the works here represented, who having sanctioned and patronised the work in its original project, kindly contributed to its progress, not only by offering every facility to his own researches, but by direct communications upon the subject to Mr. Williams, the publisher, and to himself. His especial thanks are due to the gentlemen whose names follow, and whose assistance and encouragement it is his pride to acknowledge and record:

James Walker, Esq., P.I.C.E., F.R.S., &c.
Robert Stephenson, Esq., F.R.S., M.I.C.E., &c.
John Macneil, Esq., F.R.S., F.R.A.S., &c.
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Geo. Smith, Esq., C.E.
Thos. J. Woodhouse, Esq., M.I.C.E.
&c. &c. &c.

S. C. BREES, C.E. &c.

PREFACE

TO

THE SECOND EDITION.

It is with no small degree of pride and satisfaction that the Author of "Railway Practice" ventures to lay before the Public a Second Edition of his work, within nine months of the original publication.

And a striking proof and very flattering testimonial of the high estimation in which this collection of Public Works has been held, is the circumstance of a Translation of the book having already appeared on the Continent, and that another is also in the course of publication.

It has likewise been honoured with distinguished patronage and consideration in this country, for which the Author returns his most sincere thanks, and begs to solicit a continuance of public favour.

He also feels much pleasure in stating, that several of the Engineers whose works are delineated, have expressed their approbation of the style and arrangement of the subjects in the most gratifying manner, for which he tenders his respectful obligations.

To the Editors of the several Scientific Journals and contemporary publications, who have in so liberal and candid a manner noticed his humble attempt, the Author expresses his sincere thanks.

PREFACE

TO

THE THIRD EDITION.

The First Series of Railway Practice having been out of print for some years, and the fact of the Publisher receiving constant demands for it ever since, has led to the production of this New and Improved Edition. It is hoped that the Engravings will be found to contain the same clearness in the elucidation of the subjects for which those of the former Editions were so much appreciated, while the mechanical execution will be found greatly superior.

The Series of Designs have been omitted, in order to make room for some additional Examples of Railway Works.

To the eminent Civil Engineers who have so generously patronised this Work, the Editor and Publisher return their grateful thanks, and have to add the following gentlemen to the List of Patrons, who have contributed their valuable assistance to the present Volume:

William Cubitt, Esq., F.R.S., M.I.C.E.
Peter W. Barlow, Esq., F.R.S., M.I.C.E.

*** Contributions from the Profession to the THIRD SERIES of RAILWAY PRACTICE, consisting of Engineering Works and Details, are respectfully solicited, to be addressed to

MR. S. C. BREES,

CIVIL ENGINEER AND SURVEYOR,

OFFICE FOR THE "RAILWAY PRACTICE,"

43, LINCOLN'S INN FIELDS,

NEXT DOOR TO THE COLLEGE OF SURGEONS,

LONDON.

LONDON AND BIRMINGHAM RAILWAY.*

ROBERT STEPHENSON, Esq. Engineer.

The Act for the London and Birmingham Railway was passed in May, 1833 and the Act for the Extension from the Hampstead Road to Euston Square, in July, 1835. The line was partially opened in July, 1837, and throughout in September, 1839.

This Railway has been laid out through a very difficult country, and the greatest pains have been taken to procure good gradients and curves; the prevailing gradient is consequently only 16 feet per mile, or 1 in 330, and the worst curve on the main line 600 yards radius, which occurs at the Chalk Farm Lane, near the Goods Depôt.

The standard gauge is adopted, or 4 feet $8\frac{1}{2}$ inches; intermediate space, 6 feet 5 inches; and side spaces, 7 feet 1 inch on embankments, making a total of 30 feet between the side drains.

The Terminus is very conveniently situated, the Passenger Depôt being at Euston-square, and that for the Goods at Hampstead Road, alongside of the Regent's Canal, which forms a great convenience for the further conveyance of merchandise to the Port of London.

The Euston Square Station cost	£81,532
The Camden Depôt	114,385
The Woolverton	109,454
	305,371
Total of Stations between London and Woolverton	25,386
Remaining Stations about	29,243
Total cost of Stations	£360,000

The line is worked throughout by locomotive engines at the present time, but the Extension, consisting mostly of steep inclinations, was formerly furnished with a rope and a stationary engine.

* Now called the London and North-Western Railway.

TABLE OF GRADIENTS OF THE EXTENSION.

Chains.		
$13\frac{1}{2}$	Level	Hampstead Road.
$16\frac{1}{2}$	Rise 1 in 66	Hampstead Road to Crescent Place.
17	Rise 1 in 110	Crescent Place to Park Street.
9	Rise 1 in 132	Park Street Bridge.
16	Rise 1 in 75	Park Street to Regent's Canal.

The following is about the net cost of the Railway and Furniture of the line per mile:—

Railway Works and Stations	£38,112
Land and Compensation	6,276
Carriages, Trucks, and Waggons	1,681
Engines and Tenders, &c.	1,305
Net Cost per Mile	£47,374

There are the Expenses connected with obtaining the Act of Parliament, Law Expenses, &c. &c. &c. additional.

THE PERMANENT WAY.

Vide Plate 1.

The Permanent Way of a Railway is laid after the cutting and embankments are formed, on what is called the *formation level.* The rails are secured on a bed of metalling, which consists of gravel or broken stone; gravel and loamy sand have also been used, not in a mixed state, but in separate layers. The line was originally laid partly with wood sleepers and partly with stone blocks, as shown on the plate, and the sleepers have been found the most advantageous, on account of the greater weight of the blocks having an injurious effect, particularly when lying over arches and other works.

(The permanent way of the London and Birmingham Railway cost an average of about 333*l.* per mile to keep in repair in 1839.)

The 50 lbs. to the yard, fish-bellied rails, shown on the plate, are secured to the chairs in a very peculiar manner. The rails are rolled with an angular notch on one face, and there is a hole on one side of each chair through which a small pin is inserted, which rests in the notch before stated—a split key is afterwards passed along the cheeks of the chair, and through the pin by which the latter is held in its proper position, and the rail becomes securely fixed, for although it may move longitudinally, yet it cannot rise from its bed.

A circular ball is sometimes seated in the notch, and retained by the key instead of allowing the latter to terminate there.

The joint chairs, of course, require two pins and keys, as shown upon the plate.

The mode of fixing the 65 lbs. to the yard parallel rails, shown on the plate, is the plan generally adopted at the present time. It consists of a wooden key, or tapering wedge, driven into a vacuity prepared to receive it between the cheek of the chair, and the side of the rail, by which the rail is held tight. The keys are prevented moving by the upper table of the rails, and as they become loose from shrinkage, they are tightened from time to time by a mallet. This process is, however, much diminished by the adoption of May's patent compressed wood. Mr. W. H. Barlow has obtained a patent for tubular metal keys, to be used in place of the wood; by which he proposes to afford a certain degree of elasticity at the joining of the chairs with the rails.

SPECIFICATION

Of Rails, Chairs, Wedging Bolts, Keys, and Pins, for the London and Birmingham Railway.

RAILS.

To be of malleable iron, from No. 2 Mine, entirely free from cinder, the rails being No. 3, when finished; length of rail 16 feet, parallel form, square ends; bearings 4 feet apart from centre to centre; depth $4\frac{3}{4}$ inches; width over the top $2\frac{1}{2}$ inches; 65lbs. per yard.

The precise form and dimensions of the Rail in section will be understood on reference to the accompanying full-sized Drawing, fig. 1, which represents the general section of the Rail between any two bearings. At each section the form of the bearing is changed by the vertical rib being thickened, so as to become equal in breadth to the bottom web, making the section at these points a simple T shaped Rail, as shown by the dotted lines, fig. 1.

In cutting the ends of the Rails, whatever method may be adopted, they shall, when finished, present a uniform sectional outline, accurately corresponding with the section of the adjoining portion of Rail, and exactly square with the top surface of the same.

At the works where the Rails may be manufactured, five chairs, of the description and dimensions hereinafter specified, shall be firmly fixed by spikes, at the proper distances, on a balk of timber. Into these chairs every rail as it is completed, shall be inserted, for the purpose of ascertaining that the positions of the thickened portions, forming the bearings, are properly situated, and correctly fit the recess in each chair, and that the length does not exceed or fall short of 16 feet, as no deviation will be allowed.

In addition to accurately fitting the chairs, the rails must be entirely free from any warping, and present a uniform, unbroken surface in every part, as all rails will be rejected which exhibit any symptoms of imperfect welding, whether appearing on their sides or upper surfaces.

CHAIRS.

To be made from No. 1, strong grey cast iron, and of two kinds—double or joint chair, and single or intermediate chair.

Double or joint Chair—will be accompanied by two wrought iron pins, two wrought iron wedging bolts, and two wrought iron keys. The chair to be cleanly cast, free from air-holes, sound, and correctly moulded. The recess in the chair for the reception of the rail shall not exceed the sectional dimensions of the rail more than will admit the rail to drop tightly into it. The greatest attention will be required to this fitting.

Single or intermediate Chair—will be accompanied by two wrought iron pins, one wrought iron wedging bolt, and one wrought iron key. The same care will be required in casting this chair and fitting to the rail as specified for the double chair.

WEDGING BOLTS.

The form and dimensions of the Wedging Bolts, as well as of the keys, will be understood by reference to the drawings. To be of the best malleable iron, the key-hole to be truly punched in the axis of the bolt, and the bolt to be swayed and made truly cylindrical throughout, so as to fit the hole in the chair accurately, without any play. Should the hole in the chair be rough, or otherwise untrue, it shall be carefully rimered out until the bolt fits it in the manner described. Especial care will be required to punch the hole clean and true, and in its proper position, so that before the key is driven about half home, the chisel end of the bolt shall bear firmly in the groove of the rail. All these bolts to be thoroughly case-hardened.

KEYS.

To be of malleable iron of the best quality, well hammered, split at one end, as shown in the Drawing, fig. 6, and carefully squared at the other. Each key to be uniformly tapered, so as to effect one quarter inch of draw. The thickness of the key to be uniform throughout, the tapering sides to be straight and cleanly forged.

PINS OR SPIKES.

Pins or iron Spikes for fixing the chair into the block to be 7 inches long, and 3-4ths of an inch in diameter, with a head not less than $1\frac{1}{4}$ inches in diameter, and 5-8ths of an inch in thickness.

N.B. The Directors being anxious that the most scrupulous care should be taken to form the rails, and all the other wrought iron parts above described, of the best No. 2 Mine iron only, will reserve to themselves the power of sending one or more Inspectors, either occasionally or permanently, to the works where the iron and rails are manufactured, the parties whose tender may be accepted binding themselves at all times during the progress of the execution of the above rails, chairs, &c., to afford every facility of access to such Inspectors to all parts of the works which they may deem necessary for satisfying themselves that the manufacture of the iron or rails, is in every respect in accordance with the above stipulations.

With a view of removing as much as possible all ambiguity as to the mode of manufacture, the following particulars are considered as implied by this Specification:—The iron to be refined. The puddled ball to be put under the shingling hammer and rolled into rough bars, by some called " puddled bars," by others " No. 1." These bars being cut into convenient lengths, are to be ball-furnaced, hammered, and rolled into Merchant or No. 2 bars; these bars again cut, heated as before, and rolled into rails. Parties tendering, who do not propose to follow the above method strictly, are requested to state in similar detail the process to which their tender applies. Further particulars and explanations may be had by personal application to the Engineer, at the Railway office, St John's Wood, London.

The whole of the rails, &c., specified above, are to be delivered on board a canal barge in the Pool, or on the Company's Depôt, Camden Town, on the Regent's Canal, London.

SPECIFICATION

OF THE

EXTENSION CONTRACT, No. I.

Specification of the several works to be performed in making and completing a part of the said Railway, commencing at a point marked A in a line with the faces of the Houses on the North side of a street called Drummond Street, in the Parish of Saint Pancras, in the County of Middlesex, and terminating at a point marked C, about ten yards Northward of the Towing Path of the Regent's Canal, in the same Parish.

EXTENT OF CONTRACT.

This Contract includes the formation and completion of so much of the Railway as shall be included between a point marked B at the termination of the intended Depôt, and about 275 yards from the hereinbefore named point marked A to the hereinbefore mentioned point marked C, being a distance of about 74 statute Chains.

It comprehends the following Works, viz.

The making and erecting of the Hoards or temporary fence herein specified to be erected before the commencement of any of the other works.

The formation of the whole of the Excavation Embankments and Spoil Banks represented upon the Plan.

The erection, backing and completing of the several Retaining Walls shown on the Drawings, with that of the Parapet Walls of the embankment, and the piers and arches which support them, and the pillars and iron palisading on the top of these walls.

The erection of the following Bridges, namely—

The bridge under the intended street to be called Wriothesley Street.
Ditto, 1 } On the Duke of Bedford's estate, *(these two bridges are*
Ditto, 2 } *similar in design*, Vide Plate 2.)
The bridge or covered way under the Hampstead Road, (Vide Plate 3.)
The bridge under Stanhope Place, (Vide Plate 6.)
Ditto under Crescent Place.
The bridge or covered way under Park Street, (Vide Plates 4 and 5.)
The bridge over the Regent's Canal, (Vide Plates 7, 8, 9, 10, 11, 12, 13, and 14.

The formation of and completing the several Approaches to, and Roads over each of the foregoing bridges, and the paving and flagging the road and footway in such case or cases as are shown on the drawings.

The paving and railing off the areas, flagging the footways, paving the carriage way, and erecting dwarf walls and palisades, for Wriothesley Street, as shown in the drawing.

The restoring the surface of the carriage way and footpath of Granby Street to its present condition, including the finding and fixing of the iron railing, erection of walls, and all other work necessary thereto and specified in the drawing.

The diversion of such roads as are shown on the drawings, together with the metalling and completing the roads over the Hampstead Road bridge and Park Street bridge, together with the intended new road extending from Park Street through the Oval to the Regent's Canal.

The formation of Drains in the excavations and embankments, together with those in such other places as may be specified in the contract drawings.

The laying, ballasting, and drainage of a quadruple line of permanent way.

The providing of all timber, lime, bricks, stone, iron, concrete and other materials necessary for the furtherance and completion of the works.

The doing of all other works mentioned or described in the accompanying specification and drawings.

Also, the execution of the following

EXTRA WORKS.

A wall on the north side of the Regent's Canal, similar to that in the embankment between Park Street and the Canal Bridge.

CULVERTS.

Including excavating the foundations, backing, and completing the same, of the several internal bores or diameters shown on the drawings, to be executed at the places where they may be required.

The Wing Walls to the North abutment of the Canal Bridge.

The preceding enumerated works, whether comprehended in the contract or extras, and the mode of execution, are described in the specification of each particular work, and their forms and dimensions are represented in the accompanying drawings, which are referred to in this specification; but should any discrepancies exist between the scale attached and the written dimensions, or between the drawings and specification, or any ambiguity in them, the same are to be referred to the Engineer, whose decision shall be conclusive. Also, anything contained either in the drawings or specification shall be equally binding upon the Contractor as if it were contained in both.

The written dimensions are to be taken in all cases in preference to the scale attached.

FENCING.

Immediately on obtaining possession of any part of the ground, and before the commencing of any work thereon, the Contractor shall effectually surround and enclose the same with a hoard or close paling 6 feet 6 inches in height; the situation of the hoard is shown on the plan by a black dotted line.

The hoard is to consist of uprights, 6 inches by 4 inches scantling, morticed to receive three horizontal rails of the shape shown upon the drawings, of a scantling not less than 3 inches by 2 inches, to which boards shall be nailed with good tenpenny nails, as shown in the drawings, so as to effectually prevent any one from looking through at the works. The tenons must be fixed into the mortices by wooden pegs. Should the hoard decay, or become damaged during the time that the ground inclosed by them remains in the possession of the Contractor, he shall replace it, or any part of it so damaged, with work equal to the first erection to the satisfaction of the Engineer.

All Drains, or alterations in or deviations from existing Drains or Watercourses which may be necessary for the exclusion of Water from the excavations, for the prevention of damage to the adjoining property, or for any other purpose whatever, during the progress of the works, shall be made by the Contractor, at his own expense.

EXCAVATIONS AND EMBANKMENTS.

The Part coloured Red on the Field Plan, shows the direction of the Railway, and the Area of the Land which will be purchased by the Railway Company.

The part coloured Yellow will be rented by the Railway Company, and the Contractor will have liberty to enter thereon, and erect any temporary houses, offices, &c., necessary during the progress of the works, or any machinery for excavating and embanking, which shall not be specially prohibited by Act of Parliament, for making the extension of the Railway.

The embankments are coloured Green, and the excavations Red, upon the Section of the Line.

EXCAVATIONS.

The Red line on the Section describes the tops of the embankments and bottoms of the Excavations, previous to laying the permanent way.

The Black undulating line describes the present natural Surface of the Ground along the centre line of the Railway, and shows the heights of the Embankments and depths of the Excavations, from which data their contents have been calculated, upon the supposition "that the Area of any Cross Section in sidelong ground does not differ from the Area of a similar Section in Level ground."

Plans and Sections of an Excavation, Embankment and Spoil bank, are shown in Drawing No. 24.

The Excavations are shown in the drawings, and include the excavation necessary for the Retaining Walls, and their foundations.

The Excavations shall be carried on in such lengths as the Engineer shall direct, and their sides and faces shall be supported by such timber or other mode as shall be to his satisfaction, at the expense of the Contractor, during their progress, and until the completion of the Retaining Walls.

The face of the Excavation shall in no case be carried on more than 40 feet in advance of the completed Retaining Wall, without the written permission of the Engineer.

Whenever or wherever Springs, Streams, or Soaks of Water may appear and issue from the sides of the Excavations, or any other portion of the work, the Contractor shall, at his own expense, take all such precautionary measures of

draining, damming, stopping, lading, or pumping such water, or otherwise getting rid of it, as the Engineer shall direct, in order to prevent any injurious effect, either during the progress or after the completion of the work.

EMBANKMENTS.

The Embankments to be made of such height and at such Slopes as are shown in the Section and Drawings, and the Slopes must be carefully trimmed to their proper inclinations as the work proceeds.

Each Embankment must be carried forward as nearly at the finished height and width as the allowance for shrinkage will admit of. (This must be strictly attended to in all cases, for obvious reasons,) and covered with soil 1 foot in thickness. The Contractor will also be required to cover with soil, not less than 2 feet in thickness, the whole (excepting slopes and roadway) of the Embankment or Spoil bank which is intended to form a crescent Garden on the Duke of Bedford's estate; the soil to be taken from the surface of any adjoining excavation.

The Contractor to provide himself with Tools, Labour, &c., (a similar clause will be found in the specification of 5 B, vide page 52,) for working the excavations and embankments. He must take every precautionary measure while working the Hampstead Road and Park Street Tunnels, for the safety of the metropolitan Roads.

GENERAL STIPULATIONS.

The General Stipulations are similar to 5 B, except where otherwise described, (vide pages 52, 53, 54, &c.;) also the description of the Brickwork, mortar, roman cement, concrete, backings to arches, wings and spandrels, stone imposts, (except in cases of skew arches, the skew backs of which must be worked to suit the oblique direction of the springing of the courses,) the stones (with the exception of the backs,) to be fairtooled, string courses (except to be not less than 3 feet instead of 2 feet 6 inches in length,) coping stones (except to be in 3 feet lengths instead of 2 feet, and the caps of pillars to consist of one stone;) also excavating Foundations, (the Contractor to do it at his own expense, unless the Engineer considers the foundations of any part of the works ought to be Piled, the Contractor shall do it, and be allowed for it as an Extra Work.) The descriptions of the above works are similar to those given in Contract 5 B, (commencing at page 52,) with the exceptions specified.

IRON WORK IN GENERAL.

The whole of the Cast Iron, except that otherwise specified, to be of good Grey iron of No. 1 pig. No open Sand Castings shall be allowed. All the Wrought Iron to be of best Merchants Iron. All the iron to be subject to such Tests the Engineer may think proper, provided such test does not exceed a strain of 8 Tons per inch sectional area of Wrought Iron, and 5 tons per inch sectional area in Cast Iron. The castings to be clean, smooth, and even, free from air holes and all other defects, entirely corresponding with the drawings, in the Skew Girders, the proper winde must be strictly preserved.

TIMBER.

All the Timber to be approved of by the Engineer.

ARCHES.

The method of turning the brick Arches similar to those described in 5 B, (vide page 53,) and the counterforts, abutments and spandrils shall be so worked and bonded into the arch as the Engineer shall direct. When the Arches are askew, the bricks must be laid in proper Spiral lines.

FILLING IN OVER ARCHES.

A similar clause will be found in 5 B, (vide page 53;) but the 18 inches below the surface of the roadway may be filled with broken granite, as described under the head of " metalling of roads" hereinafter described.

RETAINING WALLS IN GENERAL.

Vide Plates 2, 3, 4, 5, 6, and 7.

The various Retaining Walls are respectively shown on the several Drawings, where the several lengths, heights, inclinations, and curvatures (where such occur) are shown. The first of these Walls is that which divides Wriothesley Street from the intended Depôt, and is represented on Drawing No. 3. The next wall extends from Wriothesley Street bridge to the Hampstead Road bridge, (vide Drawing No. 5.) From this last mentioned bridge, the walls extend to Crescent

Place bridge, (vide Drawing No. 11.) From Crescent Place bridge they continue to the bridge under Park Street, as shown on Drawing No. 14. From Park Street bridge to the Regent's Canal, they are represented on Drawing No. 18.

RETAINING WALLS.

Sections and Elevations of the Retaining Walls are shown on the various drawings.

The faces of these walls will be a Curved Batter; the radius of this batter will be 50 feet, giving an average batter of $2\frac{1}{2}$ inches per foot on 20 feet in every case, excepting in the walls from Crescent Place to Park Street, which have a radius of 61 feet 8 inches, being an average batter of 2 inches to a foot on 20 feet. The whole of the brickwork of the walls will be laid in courses radiating from the supposed centre of the curve of the batter. The walls will increase in thickness the nearer they are to the foundations, by half-brick offsets, and the footings will consist of steppings of two courses of brick, projecting one-quarter of a brick.

One foot thickness of Concrete will be placed under the footings of the walls; it will project 6 inches from the footings in the front, and be flush with the neat work behind.

The space at the back of the walls shall be well Punned in with clay. The faces of the walls will be broken at intervals of 16 feet, or thereabouts, as near thereto as consistent with dividing a given length of wall into an equal number of parts, by Pilasters 4 feet by 4 inches wide, projecting half brick, built and bonded with the rest of the wall. Counterforts will be built at the back of the wall, equidistant between the pilasters, and bonded into the wall. A stone plinth 6 inches thick must be built in at the required height, and the wall above it will recede one-quarter of a brick from the face of the plinth.

In excavating for and erecting these walls, the Contractor will be required to provide at his own expense all such Centering, leading frames, plumb rules, and other implements and materials as the Engineer may deem requisite for the expedition or soundness of the works; and also such other Timbering, iron work, props, bars, and pollings as the Engineer shall think necessary for protecting the face or sides of the excavation or any other part of the work.

As soon after the erection of the walls as the Engineer shall permit or require, the Contractor shall proceed to cope them with stone. The Coping shall then be surmounted with pillars 4 feet high and 4 feet wide, capped with a weathered Cap stone 9 inches thick projecting in one stone over the several

pilasters in front of the wall. The Palisade must then be fixed between the pillars, and holes cut in the stone for their fastenings.

At the termination of the excavation beyond Park Street, the Walls change their construction and become Parapets supported on Arches, the piers of which descend through the foundations excavated in the natural ground. These piers and arches will be erected before the formation of the embankment; and the walls will be coped, and palisades and pillars fixed thereon, in the same manner as the retaining walls.

PALISADING.

The Palisading for the retaining wall is shown on Drawing No. 23, (vide Plate 3:) it is all of the same pattern, consisting of a Wrought iron Handrail riveted to lengths of cast iron open work; the handrail will be in lengths of 16 feet 6 inches or more, if required. The Castings to be 3 feet 6 inches long and about 4 feet high; they will have solid projecting feet, which must be let into the stone, and run in with lead. The whole must be constructed and fixed in a proper and workmanlike manner. The handrail shall be of the best merchant's iron, and the castings of No. 2 pig.

WRIOTHESLEY STREET BRIDGE.

This Bridge is to be built on a part of the Railway marked on the Plan, Drawing No. 2, where the balance line will be about a foot in excavation. It will cross the railway at an angle of 76 degrees, and will consist of iron, stone, and brickwork.

The foundations will be Concrete, as shown in the drawings, and hereinafter described in the specification for Stanhope Place bridge. The piers and abutments will be constructed in the same manner as those for the bridge under the Hampstead Road hereinafter described. The girders will be cast askew, and the cross arches built in the same manner as those in the bridge under Park Street hereinafter described. The coping, parapet, string-course, and dentils will be stone.

For particulars of Materials and Workmanship, see general directions hereinbefore given. The granite paving for a moiety of the road to and over this bridge to be provided and laid by the Contractor, according to the drawing; no stone must be less than 12 inches by 6 inches by 8 inches, good sound granite. The flagging must be the best Yorkshire, and the fixing of the whole, and otherwise completing the street, must be duly attended to.

BRIDGE ON THE DUKE OF BEDFORD'S ESTATE.

Vide Plate 2.

This bridge will be built at a part of the Railway marked on plan, Drawing No. 2, where the excavation is about 9 feet deep. It is Askew, crossing the railway at an angle of 76 degrees. The faces will be stone. The soffits at the arches will be laid in Spiral lines, as hereinbefore described in the general stipulations. The pier and abutment will resemble those hereinafter described for the bridge under the Hampstead Road. In other respects this bridge resembles that under Stanhope Place hereinafter described.

For particulars of materials, see general directions hereinbefore given.

BRIDGE ON THE DUKE OF BEDFORD'S ESTATE.

Vide Plate 2.

The Bridge will be built at a part of the Railway marked on Plan, Drawing No. 2, where the railway is about 13 feet in excavation. It is 5 feet wider than the last mentioned bridge between the parapets, but in other respects exactly resembles it. The Contractor is referred to drawing No. 7, and to the hereinbefore contained specification for bridge No. 1 on the Duke of Bedford's estate.

BRIDGE OR COVERED WAY UNDER HAMPSTEAD ROAD.

Vide Plate 3.

This Bridge crosses the Railway at a part marked upon the plan, where it is about 20 feet excavation. Its total length is 339 feet. It will be built on an inclination of 1 in 60. The foundation will be concrete as the other bridges. The face of the piers and abutments, the impost, plinth of the parapet, and pillars of the same, are to be stone, also the facing of the plinth of the pillars in the pier. The pier will be a series of pillars with inverts sprung between them, and the impost stone lying on the top from pillar to pillar above the opening. Each of these stones must be 6 feet long. In the abutments, the pilasters project only half a brick from the face of the wall, which increases in thickness as it gets lower. On the stone impost, and immediately over those pillars, the iron girders rest, whose ends are made flat to lie upon the stone. The Girders are curved, and have a versed sine of about 2 feet 6 inches. Each girder must be of the best No. 1 iron, and they must be proved with a weight of not less than 40 tons; Groined cross

Arches are sprung from one girder to the other the whole length of the bridge, and they must be well set in Roman cement. Two round wrought iron Bolts of not less than 2 inches in diameter must pass from the front girder through three cross arches, and be firmly keyed in.

The four Girders for the Faces of the bridge will be different from the others in their construction, and will be flat on the top to receive the stones which form the projecting string-course. An ornamental cast iron front will be bolted to each of these girders.

For particulars of materials, &c., see general directions hereinbefore given.

The Contractor will see by drawing No. 10, the houses which are intended to be taken down for the erection of this bridge, and he will be held responsible for any damage that may accrue to any other house except those specified. The lines A-B, B-C, C-D, and E-F, (on the drawing,) show the length of railing the Contractor has to erect in Granby Street.

BRIDGE UNDER STANHOPE PLACE.

Vide Plate 6.

This Bridge will be built at a part of the Railway marked 65 on the plan, where the excavation will be about 18 feet in depth. The Faces will consist of stone, and the internal structure of brickwork. The foundations will be concrete 1 foot thick, projecting 6 inches from the footings, but flush with the neat work behind. See Drawing No. 12.

The pier and faces of the Abutments will consist of a series of brick pillars and pilasters, with arches and inverts strung between them, as drawing. The Actual Abutments shall be recessed, as shown on the drawing, and set upon concrete. In case, at any time, the Contractor shall excavate too much earth, he must fill in the extra excavation with concrete, at his own expense. The stone imposts will be continued throughout the whole length of the bridge. Each arch will be a segment of a circle, with a chord 25 feet long, and with a versed sine of 2 feet 6 inches. The torous moulding must run the whole width of the bridge, and no stone can be used in it less than 4 feet in length; the parapet will be of stone, with stone pillars of the dimensions shown in the drawings, and the whole coped with stone.

The Drains must be laid in Roman cement. For particulars of materials, &c., see general directions.

BRIDGE FOR CRESCENT PLACE.

This Bridge will be built at a part of the Railway marked on the plan, where the excavation will be about 21 feet deep. The voussoires, faces of the pier and abutments, facing of the plinth, the string-course, dentels and coping, will be of stone. The spandrels, parapets, and other parts of the face of the work of malm bricks, tuck pointed, and the internal structure of good sound brickwork. The actual abutments are solid. This bridge resembles in other respects that of Stanhope Place, to which the Contractor is referred.

BRIDGE OR COVERED WAY UNDER PARK STREET.

Vide Plates 4 and 5.

This Bridge crosses the Railway at a part marked 15 on plan, where the excavation is about 22 feet. It will be built on an inclination of 1 in 135, but the soffits shall not be parallel with the rails, being 3 feet higher above the rails at the South end than at the North. The cross arches will not be groined, but the spandrels must be carried up from the girders as drawing, and the arches will then spring level for their whole width. In every other respect, the specification for the Hampstead Road bridge will apply to this.

BRIDGE OVER THE REGENT'S CANAL, NEAR CHALK FARM.

Vide Plates 7, 8, 9, 10, 11, 12, 13, and 14.

This is one of the boldest specimens of construction on the whole line, the Railway being entirely suspended by attached rods, as shown upon the several plates. We believe it is the first application of the suspension principle to carry locomotive engines and trains as used upon a Railway.

The railway platform contains four lines of rails, and is hung on wrought iron suspension rods, which are supported by massive cast iron main beams, of which there are three pair, well braced together, and spanning the canal by a length of 50 feet, and at an elevation of 12 or 13 feet above the level of the water. These beams are cast with a flat arch rising in their depth, and strong horizontal tension rods, well coupled, are fixed to counteract any inclination of the ribs to spread at the abutments. The Railway platform consists of a number of fish-bellied girders, each 28 feet long, and which are supported by the suspension rods and laid athwart the bridge. These rods are securely keyed to the main

beams. Oak beams are fixed across the girders upon which the railway chairs are secured, and cast iron gratings are filled in between the spaces, which completes the bridge.

SPECIFICATION.

This Bridge will consist of three Main Ribs of cast iron, properly secured. Each main rib will consist of two ribs, properly connected, and each of these will be cast in one piece. The Cross Girders will be secured to these ribs, and the thrust of the arch sustained by tie bolts. The open Ornamental work of the face will be bolted to the main ribs, (vide Plates 11 and 12.) The Roadway Plates to be fixed as drawing (vide Plates 11, 12, and 13), and they will be perforated for drainage. No ballasting will be laid on the bridge. The Chairs will be fixed on oak blocks, firmly secured to the girders.

Coffer Dams will have to be sunk by the Contractor at his own expense, and included in the amount of his tender, in order to get in the foundations of the abutments. Concrete will be employed in these foundations, as shown on the drawings. The Abutments will principally consist of brickwork, set in mortar, (except so much as is included between the foundations and the level of 1 foot above top water level, for 18 inches from the face of the work, which must be set in Roman cement.) The abutments will be faced with stone, and stones will have to be built and bonded in various parts, as shown on the drawings.

PILING, AND COFFER DAMS.

The Contractor shall provide and drive Cast Iron Piling,* to protect the sides or banks of the canal, in the parts directed by the Engineer. This piling must be set down in the schedule of prices, and to be provided and driven at so much per foot; and the Contractor will be paid at this rate for such quantity of piling as the Engineer shall see fit to give him written orders to drive.

Upon commencing this Bridge, the Contractor must, in the first instance, proceed to place a coffer dam around the intended site of the South Abutment, sufficient to contain the whole of the foundations described in the drawings, and well and conveniently to erect the same; he will be at liberty to withdraw the same, after the completion of the abutment, unless the Engineer should see fit to order it to be driven lower than the top of the concrete shown in the drawings, in which case the Contractor is required to cut off such piles level with the bottom of the canal. In case the Engineer should think fit to increase the length of the

* The iron sheet piling was omitted, and a brick retaining wall built instead, (Vide Plate No. 8.)—Ed.

piles, the Contractor shall be bound to provide and drive them of such length as the said Engineer may order, and is to be paid for the same at the rate contained in his schedule of prices. When the south abutment shall be raised so high as the Engineer may direct, the Contractor shall drive the iron Piling for the new towing path, which must be all driven, and the main towing path made good, before they shall proceed to excavate the foundation of the North abutment.

The girders are suspended to the bracing frames by $2\frac{1}{4}$ in. wrought iron suspension bolts; they consequently extend from rib to rib; and the oak blocks which carry the chairs are to be firmly bolted on the tops of them, as shown on the drawing.

The Roadway Plates consist of a lattice 1 inch thick, composed of 1-inch square bars, 3 inches from centre to centre. They are fixed as shown upon drawing.

Three thicknesses of patent felt are to be interposed between the bracing frames and girders, one thickness between the bracing frame and main rib, where the chipping pieces are shown in the drawing, and one thickness between the girder and oak block, fastened on the top thereof. No bolt holes are to be cast in the ribs or girders, but they are to be carefully drilled out afterwards, to fit the bolts. The mortices in the tie bolts must not be cut until the bolts have been fitted in their places and accurately marked.

ABUTMENTS.

Piles, 8 feet long and 1 foot square, are to be driven at the points noted on the plan of foundations, and iron bolts are to be keyed to them, connecting the said piles with the iron piling, in order to hold the latter in the proper place.

The Bolts are all of them the same length, and the points where the piles are to be driven are situated so that the bolts form portions of radii of the curve in which the piling is fixed. The chairs which carry the rails are fixed on the oak blocks on the top of the girders throughout the whole space between the abutments. Over the abutments they are fixed on oak beams, which rest on the abutment wall, and extend 20 feet from the face of the work, so as to ease the rails in case of the settlement of the embankment. The Rails over the bridge are wrought iron bars, 6 inches by $2\frac{1}{4}$ inches. They are fixed on chairs of the construction shown on Drawing No. 22, over the bridge, and on those generally used on the line afterwards. The Contractor must observe strictly, and not deviate in the least from the drawings and dimensions shown, unless in compliance with the written order of the Engineer. The Contractor is to do it all in a thorough

workmanlike manner, and no work shall be allowed to pass without the approval of the Engineer; his order must be strictly attended to in every case. The Contractor to provide himself with all machinery, implements, labour, &c., deemed necessary by the Engineer for the furtherance of the work. Each Girder must be tested to 40 tons, and each Tie Bolt to 65 tons. For particulars not contained in this part of the specification, the Contractor is referred to the general directions.

BALLASTING AND LAYING THE PERMANENT WAY.

A similar clause will be found in 5 B, except that there will be a four-fold way of single Lines of Rails, and they will fall from the point A marked on the Section of the Line to the point B, at the uniform rate of 1 in 156, or 0.423 feet per chain; from the point B to the point C at the rate of 1 in 286, or 0.237 feet in a chain. From this point to the point D it will rise at the uniform rate of 1 in 60, or 1.1 feet in a chain; from the point D to E it will rise at the rate of 1 in 135, or 0.4888 feet in a chain; it will then rise 1 in 75, or 0.88 feet per chain, and continue at this level to the end of the contract. The two outside lines of the way are to be 6 feet apart, and as drawing. There shall be cross drains 30 feet apart, and a sink trap with iron grating to each alternate cross drain.

DISPOSAL OF MATERIAL.

The Contractor must calculate the quantity of earth contained in each of these several embankments from the heights given on the plan, the slopes being 1 to 1. The embankment between Park Street and the Canal will have to be formed from part of the remaining contents of the excavations, and the surplus material must be then carried over the canal, and will form the embankment adjoining the Chalk Farm depôt.

Notwithstanding these arrangements, the Company reserve to themselves the power to order the Contractor to lay out part of the material excavated on the site of the intended depôt at Euston Grove.

TIME OF COMPLETION.

The whole of the above described works are to be completed on or before the 1st of January, 1837.

SPECIFICATION

Of the several Works to be done in making and completing a Part of the London and Birmingham Railway. (First Contract joining the Extension.)

EXTENT OF CONTRACT, AND GENERAL STIPULATIONS.

This Contract commences at the Depôt, near the intersection of the Hampstead Road with the Regent's Canal, and terminates at the River Brent, including a length of about 5¾ miles.

It comprehends the following Works:—

The making of the Temporary Fences necessary during the progress of the other works.

The making of the Permanent Fencing.

The formation of the whole of the Excavations and Embankments.

The raising of the Land for the proposed Depôt.

Making and completing the Tunnels under Primrose Hill, and the London and Harrow Road, near Kensal Green.

The erection of the Bridges over the Railway at the crossing of the private road from Paddington to Hampstead.

Ditto at the crossing of the London and Edgeware Road, near Kilburn.

Ditto at the crossing of the Railway over the road to Wormwood Scrubs, called Mitre Lane.

Ditto at the crossing of the Railway over the road from Halesdon Green to Acton.

The making and completing of the Approaches to each of the foregoing Bridges.

The erection of the Bridge over the River Brent.

The making of the Culverts under the Railway for the Serpentine River and Canal Feeder, and all other Culverts shown on the Section.

The laying and ballasting of the Permanent Way, including the providing of all timber, bricks, lime, stone, or other materials necessary for the completion of the Works. *The iron rails, chairs, keys, pins, trenails, blocks, and sleepers for the purpose, being provided by the Company.*

Also, the execution of the following

EXTRA WORKS.

The erection of Gates.

The excavation and embanking of sloped Occupation Bridges.

The metalling of Occupation Roads.

The paving of Roads crossing the Railway on a level.

The building of Occupation Bridges and Culverts.

The laying and ballasting Permanent Sidings, and the formation of Tool recesses, are considered as extra works, and will be paid for as such, according to the schedule of prices for extra works set out in the Tender.

The preceding enumerated works, and the mode of execution, are described at length in the Specification of each particular work, and their forms and dimensions described in the accompanying drawings, which are referred to in each specification. But should any discrepancies exist between the measurement by the scale attached and the written dimensions, the same is to be referred to the Engineer, whose decision shall be conclusive. Anything contained either in the Drawings or Specification shall be considered as contained in both. The written dimensions are those by which it is intended the Contractor shall make his estimate.

EXCAVATIONS AND EMBANKMENTS.

The part coloured Red in the Plan shows the direction of the Railway, and the area of land which will be purchased by the Railway Company, and upon which the Contractor shall have full permission to erect any temporary houses, offices, &c., necessary during the execution of the works, or any machinery for excavating, embanking, or tunnelling, provided that such proposed erections shall not be specially prohibited by the Act for making the Railway. The Embankments are coloured light red, and the excavations of a deeper red. The Red line on the section describes the tops of the embankments and bottoms of the excavations, previous to the laying and ballasting of the Permanent Way.

The Black undulating line describes the present natural surface of the ground along the centre line of the Railway, showing the respective heights of the

embankments and depths of the excavations; from which data their contents have been calculated, on the supposition that the area of any cross section in sideling ground does not differ from the area of a similar section in level ground. The levels from which the section is made are believed to be accurate, but the Contractor must verify the results, as he will be held liable to the consequence of any errors.

EMBANKMENTS.

The whole of the Embankments in this Contract shall have slopes of 2 to 1 (that is to say), where the base of the slope is two feet, its height shall be 1 foot only; and they shall be 33 feet wide at the level of the red line in the section, neither more nor less.

Each of the Embankments shall be uniformly carried forward as nearly as the finished heights and width as the due allowance for shrinking of the materials will admit of; and this allowance shall not exceed or fall short of the quantity deemed necessary by the Engineer. In all cases, this must be carefully and strictly attended to, in order to avoid the necessity of making any subsequent addition either to heights or the width of the embankment, to bring them to the proper level and dimensions.

The surface of the Embankment shall be kept in such form, or be intersected by such drains, as will always prevent the formation of pools of water upon them, and insure the Embankment being kept as dry as possible.

Whenever the material teemed over the end of the Embankment shall not form the proper slope, it shall be carefully trimmed to its required form; and this operation must proceed at the same time with the end of the Embankment, so as to obviate the necessity of any future addition of material to the sides of the Embankment.

As the Embankments advance and become consolidated, the slopes shall be carefully trimmed into planes, having the proper slope, and be neatly covered with an uniform substance of turf of not less than 8 inches in thickness, and laid with the greensward outwards. The turf must be taken from the ground to be occupied by the base of the Embankment, and cut square, so as to be laid on the slopes in the form of flags; and where the land is arable, the slopes of the Embankments shall be covered with the soil. It must be uniformly laid on of the thickness of 6 inches, and sown with rye grass and clover seed as soon as the proper season will admit of its being done; not less than one pound and a half of clover seed, and one pound and a half of rye grass seed, to be sown on each acre.

When the material brought to the Embankment consists of large lumps, they shall be broken into pieces of not more than 6 inches in diameter.

EXCAVATIONS.

The excavations in this Contract shall be 33 feet wide at the level of the Red line on the Section. Between Chalk Farm Lane and the private road from Paddington to Hampstead, the slopes shall have 3 feet base for every foot in height, and from the last mentioned place to the termination of the Contract, the slopes shall have two feet base for every foot in height.

The slopes of the excavation shall be finished as the cutting advances, and be neatly and uniformly dressed to the specified inclination as near to the face of the cutting as possible. As soon as any part of the slopes are dressed to the proper inclination, they shall be covered with turf taken from the land to be occupied by the excavations, in the same manner as before directed in the Specifications of the Embankment; and when turf cannot be obtained, the slopes must be covered with soil, and sown with rye grass, and clover seed, as before directed in the Specifications of the Embankment.

Whenever and wherever springs, soaks, or streams of water may appear, and issue from the face of the slopes, the Contractor shall be bound to make and maintain, during the progress, and until the completion of the works, such drains or watercourses as shall completely and effectually prevent the said springs, soaks, or streams of water from injuring the slopes, and shall convey the whole of such water into proper drains, so that none shall be permitted to lodge in the excavation; and where beds of sand, gravel, or other loose mould occur, the face of the slope must be protected from the injurious effects of such springs or streams of water by any other means that may be advisable or necessary.

At the bottom of each slope a drain of an uniform depth below the rails, as shown in the Drawings, shall be made, and these drains must be continued on both sides under all the bridges which cross the Railway. A drain shall also be made at the top of each slope, so as to exclude from the excavations any water draining off or flowing from the land; and all covered or open drains which may be intersected by the excavation, must be made to discharge their water into the ditch at the outside of the top of the slope, for which purpose the said ditch shall be made as deep, at least, as the bottom of the intersected drain, and the space between the outside drain and the slope shall be well puddled at the point of intersection. The Contractor shall also be compelled to open or make any new drain which the Engineer may deem necessary for the exclusion of any water from the Railway excavations.

In the formation of the Excavations and Embankments, the Contractor must provide, at his own expense, all the necessary rails, chairs, keys, pins, blocks, and sleepers, as well as waggons, barrows, planks, or other machinery, materials or utensils, which stipulation is, however, modified to a certain extent by the following conditions:

It is not intended to deliver to the Contractor any of the permanent rails, chairs, keys, pins, blocks, or sleepers, until the completion of at least one continuous mile of roadway, which distance must be certified by the Engineer as being ready for the reception of the Permanent Ballasting, in which case a sufficient number of rails, chairs, keys, pins, blocks, and sleepers, shall be delivered to the Contractor, who will be permitted to use them in such a manner only as is hereinafter described in the Specification of the Ballasting and laying the Permanent Way.

FENCING AND DITCHING.

The Fencing and Ditching described in the following Specifications is of two kinds: the first temporary, for the protection of the lands adjoining the Railway, during the progress and until the completion of the works; the second permanent, for the inclosure of the Railway when finished.

TEMPORARY FENCING.

Immediately after the delivery of any portion of the site of the intended Railway into the possession of the Contractor, and previous to the commencement of the other works, the Temporary Fencing shall be completed, and shall include the whole area of land occupied by any of the works contained in the Contract. The temporary fencing shall consist of split oak posts, placed nine feet apart, and 3½ feet high above the ground, morticed for the reception of 3 horizontal oak or larch rails, which are also to be supported by an intermediate stay or brick post firmly nailed to each of the rails. The whole of this fencing must be firmly and substantially fixed so as to exclude sheep, pigs, and all cattle from the excavations and other works, and effectually prevent the adjoining lands from trespass during the progress of the works.

All drains or alterations, or deviations in existing drains or water-courses, necessary either for the exclusion of water from the cuttings, or for the prevention of damage to the adjoining property, or any other whatever, shall be made by the contractor at his own expense.

PERMANENT FENCING.

The Permanent Fencing is of two kinds, as follows:—

First,—Wood railing extending from Chalk Farm Lane to the Depôt. This portion of the Fencing is to be made with oak posts constructed in the manner shown in the Drawing. The wood railing is to be placed on both sides of the Railway, on the edge of each slope, at the top of the embankment. The posts and rails shall be of good oak, free from sap, and straight grained. The rails, and so much of the posts as are seen above ground shall be sawn out square, and neatly planed to the proper dimensions. Each post shall have 4 mortices passing completely through it, and shall stand 4 feet above the level of the rails. The posts are to be placed 6 feet apart, and each rail shall be equal in length to two spaces, or 12 feet, passing through every alternate post. The ends of the rails must be fitted exactly into the mortices of the posts, and secured with small oak trenails. The bottom of every post shall be well charred before fixing in the ground; all the joints must be made with white lead, and the whole of the wood above the ground painted with two coats of stone-coloured paint. At the bottom of the slopes of the embankment, a ditch shall be made, as shown in Drawing, for the purpose of carrying off the water draining from the slopes, which must be continued to the nearest drain by which the drainage of the adjoining fields is at present effected.

The whole of the Fencing must be made at such times as may be directed by the Company's Engineer.

Second,—Brick Walls, extending from Chalk Farm Lane to the beginning of Primrose Hill Tunnel, and from the other end of the same Tunnel to the Bridge under the London and Edgware Road at Kilburn.

This fencing shall consist of brick walls at the bottom of the Cuttings on each side of the Railway, 26 feet apart, equi-distant from the centre of the Railway, and running parallel to the rails. The wall shall be made of the same dimensions and form shown in the Drawing. The height, exclusive of the coping, shall be 3 feet above the upper surface of the rails.

The footings shall be carried at least 1 foot below the bottom of the ditch: and if the ditches shall have been made deeper than directed, then the footings shall be carried as much lower as the Engineer may deem necessary, and this additional depth shall be made by the Contractor at his own expense. Holes, as represented in the Drawing, must be left in the bottom of each wall to allow the water to drain freely from the ballast of Railway. The walls are to be finished

with a stone coping of Bramley Hall or Derbyshire stone, 6 inches in thickness, and projecting 1 inch beyond each side of the walls. The brickwork is to be built with good sound and well burnt grey stocks, laid in good mortar, made with Merstham or Dorking lime, and clean sharp sand, in the proportion of three measures of sand to one of lime. The lime is to be slaked and screened with the sand, both in a dry state, and well tempered with water afterwards. The brickwork is to be flushed in solid, with mortar laid with a neat close joint, and no joint of mortar to exceed one-quarter of an inch in thickness. The outside joints are to be neatly drawn.

The drains or ditches between the walls and the bottom of the adjoining slopes must be made as shown in Drawing, and kept open until the whole of the works are completed. Quick fencing and ditching, extending from the bridge under the Edgware Road and London Road to the River Brent, excepting the space occupied by the Tunnel under the London and Harrow Road, near Kensal Green. This part of the fencing is to be placed within the limits of fifteen feet from the termination of the slopes. A ditch of 6 feet wide at the top, 2 feet wide at the bottom, and 2 feet deep, shall be made on the higher side of the ground to be occupied by the Railway, and a ditch of 3 feet wide at the top, 1 foot wide at the bottom, and one foot deep, on the lower side of the ground. The outside of the ditch must be 5 feet distant from the boundary of the land occupied by the Railway, and if the last mentioned ditch shall be deemed insufficient in any particular case, the larger sized ditch shall be made instead. The material excavated from the ditch shall be used to form a mound, both sides of which shall be neatly faced with turf. When the material excavated from the ditch shall be more in quantity than sufficient to form the mound, the surplus must be conveyed to the nearest embankment. The best portion of the vegetable soil excavated from the ditch shall be placed in the middle of the mound, on which a double row of good 3-year quicks, 2 years transplanted, shall be planted, and not less than 24 quicksets shall be contained in one lineal yard. On the inner edge of the ditch, oak posts and rails must be placed to protect the quicks. The posts are to be of split oak, 7 feet in length, and equal at least to 5 inches by $3\frac{1}{2}$ inches in sectional area; they are to be placed at a distance of 9 feet from centre to centre, and to stand $3\frac{1}{2}$ feet above the top of the quick ground. Each post is to have 3 mortices for the reception of the ends of the rails, to be made of split oak, and to be as nearly of a uniform size as possible. The horizontal rails, three in number, between each pair of posts are to be of split oak or larch, equal to $3\frac{1}{2}$ inches, by $1\frac{1}{2}$ inch in sectional area, and 10 feet in length, and the ends are to be scarfed so as to fill the mortices of the posts. Midway between the posts, an oak or larch stay, 5

feet long, 3 inches wide, and $1\frac{1}{2}$ inch thick, is to be firmly nailed to each of three horizontal rails with good tenpenny nails.

The posts must be firmly fixed in the ground, the ends of the rails driven firmly into the mortices of the posts, and a piece of new hoop iron, $1\frac{1}{4}$ inch wide, shall be nailed round the top of every post to prevent its splitting. The fencing shall be made with as few bendings as the nature of the ground will admit of, and the ditch alongside of the mound, shall descend as uniformly as possible to the nearest main drain, or water-course, by which the drainage of the adjoining lands is at present effected.

The permanent fencing shall proceed as rapidly as the progress of the other works, and the nature of the season will admit of. Such parts of the temporary fencing as can be made available, shall be permitted to be used in the permanent fencing, provided the material be of the requisite strength and quality, and uninjured in other respects by its previous use. At the bottom of the embankments, small draining tiles shall be laid through the quick mound, at intervals of not more than 100 yards, in order to convey the water draining from the slopes into the fence ditches.

Such parts of the permanent fencing as shall have been completed before the finishing of the other parts of the work, shall be kept in complete order by the Contractor. The quicks shall be cleaned or weeded twice, at least, a year, and any broken rails, or posts, or stays replaced by new ones, equal in quality to those originally used. All the quicksets which may not take root and grow, must be pulled up and 3-year old living quicksets, similar to those before described, planted in their stead.

PRIMROSE HILL TUNNEL.

Plates 15 *and* 16 *describe the Method of Working the Tunnel.*

SPECIFICATION.

These Plates show the successive stages in the construction of the tunnel from the commencement of the working shaft to the brick arching. A tunnel is commenced by *trial shafts*, which follow the borings; and other shafts, called *air shafts*, are also constructed, to ventilate the tunnel works. The workmen, with their tools and materials, descend, and the soil excavated is conveyed to the surface of the ground by the *working shafts*.

Upon the shafts being carried down to the level of the top of the tunnel, a small square horizontal boring, termed a *heading* or *driftway*, is generally excavated in the line of the intended tunnel about 10 or 12 feet long, 3 or 4 feet wide, and of nearly the same height, and sufficient to afford the miners room to

use their tools. The excavation is required to be a little larger than the bore of the tunnel, in order to allow space for the necessary shorings, bars, and pollings to support the several faces of the work while the centering is being brought forward; due allowance is also required to be made for the settling of the pollings, and which always occurs. The top face of the heading serves as a guide to the miners, and represents the upper surface of the excavation. Upon the brickwork being sufficiently advanced, the bars and pollings are withdrawn, and the timber centering moved on a stage; the excavation then proceeds as before. The back of the arch must always be filled up solid with brick, packing, or some other hard materials; and if any of the bars cannot be drawn out readily, they are bricked in. The miners should never be more than 6 or 8 feet in advance of the bricklayers, in order to guard against accidents from any subsidence of the earth. The heading is sometimes continued from shaft to shaft; and upon the works of two contiguous shafts approaching near each other, a heading should always precede the main excavation.

It was found necessary to execute this tunnel in 3 bricks laid in cement, instead of 2, as originally intended.

This tunnel commences in the Eaton College Estate, 550 yards from Chalk Farm Lane, and terminates near the Road leading from Saint John's Wood to Finchley. The length is equal to 50 and 1-5th statute chains; the other dimensions, situation, and construction of the several parts, are minutely described on the Plan and Section of the Line and Drawings.

The area of ground on the top of the tunnel to which the Contractor must confine his operations on the surface, is one statute chain wide for the whole length of the tunnel, which must be fenced off on both sides with temporary fencing.

All the General Stipulations in the Specification, respecting the extension of land, &c., must be considered applicable to this part of the Contract, where no special directions are given.

The tunnel is to be made with a circular brick arch and curved side walls, resting on stone footings or skew backs, the whole being supported by a brick invert or counter arch. The ends will be made with curved brick walls, as shown in the Drawings.

A cast-iron plate is to be let into the arch near the end, and connected by bolts to another plate built into the arch, 100 feet distant from the first.*

* Vide Plate 17, which represents the details of iron plates for tunnel fronts. In the Primrose Hill Tunnel, which was executed in 3 bricks in cement, the front plate was placed in the centre of the wall with connecting rods 100 feet in length, to another fixed in the arching, but the method shown in the above is considered to be an improvement.

MATERIALS.

The whole of the bricks used in the construction of the tunnel, shafts, and end, shall be sound, good, hard, well burnt grey stocks; the freestone used shall be Bramley Hall, or other stone equally good, perfectly sound and free from flaws.

The Cast iron, and Wrought iron, must be of the best quality, and subject to any examination the Engineer may deem necessary. The mortar used in the tunnel shall be made from the fresh-burnt Merstham lime, or other lime, which the Engineer may deem equally good; it shall be ground in its dry and unslaked state, under hedge-stones. The sand must be sharp, clean sand, and shall be mixed with the lime in the proportion of 3 of sand, to 1 of lime.

The lime and sand must be intimately mixed and worked with a proper quantity of water in a pug-mill as required for use.

The Contractor shall sink 4 shafts, and no more, on the centre line of the tunnel, at convenient distances; they shall be 8 feet in diameter within the brick-work, which shall be of 1 brick in length; each shaft shall be of the same diameter from the top to the bottom, perfectly cylindrical, free from bulges and other distortions; the brickwork shall be laid in 2 half brick rings, with the joints properly broken, and flushed in solid with mortar. The bricks must be moulded to fit the circumference of the shaft; where each intersects the top of the arch of the tunnel, a cast-iron curb or ring, of the same diameter as the shaft, shall be inserted in the brickwork of the arch, and upon it the shaft must be built. No wood curbs will be permitted to be built in the brickwork of the shafts.

Where any water may occur in sinking, it must be completely excluded from the shafts or tunnel by a lining or puddle behind the brickwork of the shafts, or by laying the brickwork in Roman cement, or by the adoption of any other means the Engineer may judge expedient or necessary.

The arch and side walls are to be 2 bricks thick, the invert one brick and a half thick, throughout the whole length of the tunnel, except in cases where the material, through which the tunnel will pass, may, in the opinion of the Engineer, require either a greater or less thickness of brickwork in the arch, side walls, or invert.

In all such cases, the Contractor shall make the brickwork of such thickness as the Engineer may direct, the Contractor being paid for any increase in the

quantity of brickwork or excavation, and making any allowance to the Company for any decrease at the rate stated in the Schedule.

The invert or counter-arch, of whatever thickness it may be, shall be carefully laid and bonded; the side walls shall be laid in English bond; the arch, if one brick and a half thick, shall be built in 3 several half brick rings; if 2 bricks, in 4 half brick rings; and so on, each ring containing 5 courses of bricks more than the inner one immediately preceding it. The footings, or skew-backs of the side walls, shall be made of Bramley Hall Stone, of the sectional form shown in the enlarged Drawing, and in lengths of not less than 3 feet; they shall have a bed of brickwork extending from the inverted arch as shown in the Drawing. The skewback must be carefully bedded in the brickwork in its proper position.

The mortar in which the brickwork is set, shall be as little in quantity, and as uniform in thickness between the joints, as is consistent with making the arch, side-walls, and invert, firm and solid throughout. The horizontal courses must be kept perfectly straight in the direction of the tunnel, and parallel with the surface of the rails.

Should, at any time, the regular continuity of the arch or side walls be destroyed, either from the irregular shrinking of the arch, or imperfect fixing of the centres or any other cause whatever, the Contractor must remove and amend the irregularities in a satisfactory manner.

Wherever water may occur and flow into the tunnel, and it shall be deemed expedient by the Engineer to lay any part of the brickwork in Roman cement, the Contractor shall be paid for so doing such an additional sum per rod of 306 cubic feet, as may be stated in the Schedule of Prices.

EXCAVATIONS.

The Contractor shall be at liberty to make an open cutting at each end of the tunnel, not exceeding 20 yards in length, nor wider than the outside of the brickwork of the tunnel. The sides of the excavation shall be supported and kept open by suitable timber, in such a manner as to prevent slipping, until the whole of the brickwork is completed in that length. The open space shall then be filled up to the original surface by layers of clay of not more than 1 foot thickness, each of which shall be carefully punned, before laying on the succeeding layer. The soil of turf must be laid aside before making the excavation, and neatly replaced when filled up. The excavation shall then proceed in the usual way under the surface.

In no case shall the excavation be carried more than 6 feet in advance of the brickwork, and should any deterioration or change in the strata occur, which may appear to the Engineer to require this distance to be reduced, the Contractor shall regulate this distance by the direction of the Engineer.

In making the excavations, great care must be taken that they do not in any way exceed the area necessary for the reception of the brickwork, and the vacant space, if any, between the sides or roof of the excavation and brickwork shall be filled with clay, and rammed in solid with proper beaters, so as to avoid any distortion in the form of the tunnel from irregular pressure.

The foundation for the reception of the invert or counter-arch shall be cut out to the exact form and depth required, before any part of the brickwork is laid, and should any unavoidable irregularity be found to exist, it must be made up with dry clay or clean gravel, firmly rammed by beaters.

The whole of the material excavated, excepting that required to back the arch, whether taken from the shaft or either end, shall be conveyed into the proposed depôt, and disposed of in the same way as the excavation, marked No. 1 in the Section. No material shall be taken out of the end near St. John's Wood Road, unless specially directed by the Engineer.

In the execution of this part of his Contract, the Contractor shall provide all the necessary materials and machinery for executing the same; make all the necessary shafts, bore-holes, and perform every operation necessary for completing the work in the manner intended by the Specifications; all the machinery, centering, &c., must be constructed in such manner as the Engineer may approve.

All air shafts which it may be necessary to make, shall be made in the same manner as the larger shafts, and stand upon cast iron curbs of proportionate shapes and dimensions.

Any drainage to the land by the falling of the surface during the execution of the work, shall be paid for by the Contractor.

Marks or signals will be, from time to time given to the Contractor by the Company's Engineers, for the purpose of regulating the direction and level of the tunnel, and the Contractor shall be at the expense of erecting any temporary or permanent marks or signals which may be considered necessary for giving the direction and levels with the required accuracy.

Whenever the faces of the excavations between two adjoining shafts, or shaft and end, shall have approached within fifty yards of each other, the Contractor shall drive a heading from the one to the other.

The slopes of the land over the ends of the tunnel are to be made at the same inclination as the side of the excavation adjoining. A ditch must be cut

round the top, similar to that of the adjoining slopes, and joined thereto. The slope must be made with puddle 4 feet in depth at the base, and carried in at same level 12 feet, and made up to the surface.

A cast-iron drain, as shown in Drawing, is to be laid in the bottom of the tunnel, midway between the two Railways, and through the whole length of the tunnel. The connexions of the several pieces must be properly and accurately made, and the drain must communicate with the side drains of the excavation by two cast-iron side branches at each end.

BRIDGE OVER THE RAILWAY AT THE CROSSING OF PRIVATE ROAD FROM PADDINGTON TO HAMPSTEAD.

The road above mentioned crosses the Railway at a point where the excavation is about 4 feet in depth, requiring the road to be raised to the height of $22\frac{1}{2}$ feet above the level of the Railway.

The footings of the abutments will be made 18 inches below the level of the red line in the Section, and each abutment will be strengthened by a counterfort placed at the back.

The arch will be an ellipse, having above it a projecting band of brickwork, surmounted by a stone string-course; upon this will be placed the parapet wall, with a brick plinth and surmounted by a stone coping.

The wing walls extend into the embankments of the approaches, and their foundations must be made, at least, as low as is shown in the Drawings.

ABUTMENTS.

The form and dimensions of the abutments are shown at A A A A, Figures 1, 2, 3, and 4; their faces will be perpendicular, their thickness being diminished from the bottom to the top by half-brick offsets at the back. The abutments must be built in a solid and substantial manner.

COUNTERFORTS.

The Counterforts must be built in the situation, and of the form and dimensions shown at B B in the Drawings. The courses shall be laid as shown at right angles to the drift of the arch; they must be built in a solid manner, properly bonded into the substance of the abutments.

ARCH.

The arch will be of an elliptical form, as shown at C C; it must be altogether constructed of whole bricks, laid in such manner as the Engineer may direct.

As many courses as shall be included in 4 feet on each side of the top of the arch, shall be laid in the best Roman cement, and with straight picked bricks.

The remainder of the arch shall be laid in mortar with a close joint, and the soffit of the arch neatly pointed after the removal of the centres.

The bricks in the face of the arch shall be rubbed on their faces, and neatly pointed; great care must be taken in the proper summering of the bricks in the arch, and any irregularity of form from imperfections in the laggings or centre, shall be removed and amended by the Contractor.

BACKING.

The brickwork forming the Backing D D of the arch, shall be laid in a solid and substantial manner, each brick properly breaking joint with the next, in the same manner as the outside work.

WING WALLS.

The Wing Walls, E E, are to be built of the form and dimensions shown in the Drawing; battering both on the outside and inside, and the courses to be properly bonded with the abutments.

SPANDREL WALLS.

The Spandrel Walls, F F, are to be of the form and dimensions shown in the Drawing; to be well bonded with the backing, and the bricks neatly cut to fit the curve of the arch.

PARAPETS.

The Parapet walls, G G, are to be of the lengths and dimensions shown in the Drawing; the courses are to be run straight the whole length, and the sides of walls to be parallel and fair.

STRING COURSE.

A stone String Course, as shown in the Drawing, shall extend the whole distance between the outsides of the two abutments. The String Course on the walls, shall be of brick laid in Roman cement, and the upper arises of the bricks rubbed off.

COPING.

The Coping, H H, is to be of stone, of the form shown in the Drawing. No stone shall be less than 3 feet in length. The Coping shall run the whole length of the parapet wall, and be laid perfectly straight. The stones shall be dowelled together with iron dowels fixed with lead. All the faces of the copings and String Course are to be fair bored, and, if required, rubbed in their front faces.

The spaces between the brickwork and side excavation for containing it, shall be filled up with clay as the work advances, and firmly rammed in with proper beaters.

The space between the wing walls shall be filled to its proper height, and clay lain in layers of 1 foot in thickness, and each layer well punned before adding the succeeding one, the whole of the clay shall be filled in up to the surface before removing the centres.

MATERIALS.

Bricks.—The bricks are to be hard, sound, and well-burnt grey-stocks, of uniform size and colour for the fronts.

Mortar.—The mortar shall be made from the fresh-burnt Merstham or Dorking lime, and clean sharp sand, screened together, both in a dry state, in the proportion of one measure of lime to three of sand. They must be intimately mixed, and well tempered with a proper quantity of water.

Roman Cement.—Where directed to be used, shall be of the best quality, recently made, mixed with an equal quantity of sand, and only mixed when required for use.

Stone.—The stone shall be good Bramley Fall, or other similar stone, equally good, free from flaws and iron shot.

General Clause.—The walls &c. shall be laid either in Flemish or English bond, as the Engineer may direct, and in no case shall any point of mortar exceed one quarter of an inch in thickness. No broken bricks will be permitted to be

used, either externally or internally, unless absolutely necessary as closers, nor shall any difference be made in the goodness of the workmanship of the interior or exterior of the work.

The whole of the brickwork shall be well grouted at every course. The parapets and string-courses shall not be made until after the removal of the centres.

All the centering must be such as shall be approved of by the Engineer, and in no case shall the centres be struck before his permission has been obtained.

EXTRA, OR CONTINGENT WORKS.

Fence Gates.—The Fence Gates are to be made of the form and dimensions shown in the Drawing. The heels and heads are to be of good oak sawn out to the proper dimensions, and morticed for the reception of the horizontal bars.

The horizontal bars are to be five in number, of cleft oak, and smoothed over. The ends must fit the mortices of the heels and heads, and be secured by oak pins. The diagonal braces are similar to the bars, and to be firmly nailed to the bars; the nails to pass through both, and their points clenched.

The posts to be of oak, the top sawn to the dimensions and form, with a small cap on each; the bottom of the posts must be charred. The gate irons shall be of the form shown, and shall not weigh less than fourteen pounds per set. The gates must be firmly fixed in the line of the quicksets, and the wood railing neatly joined to the gate-posts. The gates and posts must be painted with two coats of white or stone-coloured paint.

EXCAVATIONS AND EMBANKMENTS OF SLOPED OCCUPATION ROADS.

These Excavations and Embankments are to be made in the same manner as those on the line of Railway, and with such slopes as may be directed. The contents of the excavation shall be conveyed to the nearest embankment or spoil bank. The embankments are to be made from the surplus materials in the excavations; when made to form the approaches to a bridge, they must be carefully punned in between the wing walls.

METALLING OCCUPATION BRIDGES.

This is to be done in the same manner as described in the Specification of the approaches to Bridges

PAVING CROSSINGS.

All the roads crossing the Railway without bridges are to be paved in the manner shown in Drawing, with good 6 or 7-inch paving of Aberdeen, or other granite equally good. The Paving must be laid on a bed of fine clean gravel of 12 inches in thickness, in a solid and substantial manner. The paving stones must be cubes as nearly as possible. Each rail must be protected by two iron bars, as shown in the Drawing; they will be considered part of the rails, and provided by the Company.

OCCUPATION BRIDGES.

These Bridges will be similar in form and construction to the bridge at the crossing of the private road from Paddington to Hampstead. The same directions will apply to the workmanship and material in both.

CULVERTS.

The Culverts are to be built in the same manner as those previously described in the former part of the Specification; they are to be built of the forms and dimensions shown in Drawing, the sizes being selected to suit the particular situation.

LAYING AND BALLASTING PERMANENT SIDINGS.

The Sidings are to be laid in such positions and of such lengths as may be directed by the Engineer. They must be laid in the form and manner shown in the Drawing. The Contractor will be required to take up any part of the rails already laid that may be found necessary; to cut them into proper lengths for the reception of other iron work, to relay them, and to fix all the necessary crossing plates, check rails, moveable points, or sliding rails, with the requisite machinery for moving them.

The whole must be made equally as firm and substantial as the other parts of the permanent way.

The Specification of the Permanent Ballasting already described must be considered equally applicable to the construction of the Sidings.

CONTRACT No. 5, B.

SPECIFICATIÓN of the several Works to be performed in making and completing a part of the said Railway, commencing at a point marked A on the Section, and corresponding with a pole on Boxmoor, 16 chains south of the Grand Junction Canal, in the parish of Hemel Hempstead, in the county of Hertford, and extending to a point marked B on the Section, 25 chains North of the road leading from Northchurch to Little Gaddesden and Ashridge, in the parish of Berkhampstead in the said county.

EXTENT OF CONTRACT, AND GENERAL STIPULATIONS.

This Contract is to include the formation and completion of so much of the Railway as shall be included in the limits mentioned above, being a distance of about 350 chains.

It comprehends the following Works:

The making of the Temporary Fences necessary during the progress of the works.

The making of the Permanent Fences.

The formation of the whole of the Excavations and Embankments represented on the Section of the Line Drawing No. 2.

The erection of the following Bridges:

- The Bridge at the crossing of the Grand Junction Canal.
- Ditto at the crossing of the road from Bourne End to Pouching End, (Vide Plate 18.)
- Ditto at the crossing of the road from Haxter's End, (Vide Plate 19.)
- Ditto at the crossing of the road from Great Gaddesden to Berkhampstead, (Vide Plate 20.)
- Ditto at the crossing of another road from Great Gaddesden to Berkhampstead.
- Ditto at the crossing of the road from Berkhampstead to Berkhampstead Place, (Vide Plate 40.)

The making, metalling, and completing the Approaches to each of the foregoing bridges.

The making a Paved Crossing for the road from Berkhampstead Common, and completing the approaches to the same.

The Diversion of such Roads as may be required, and are shown on drawings, with the metalling and completing the same.

The building a Retaining Wall opposite Berkhampstead Castle.

The making and completing the Tunnel called Northchurch Tunnel, (Vide Plates 27, 28, 29, and 30.)

The formation of side drains in the excavations on each side of the railway.

The laying, ballasting, and drainage of the Permanent Way, including the providing of all Timber, bricks, lime, stone, or other materials necessary for the completion of the works. The iron rails, chairs, keys, pins, trenails, blocks, and sleepers for the purpose, being provided by the Company, under conditions hereinafter described, (Vide Plate 1.)

The doing of all other works mentioned or described in the accompanying drawings or specifications.

Also, the execution of the following

EXTRA WORKS.

The erection of Gates.

The excavation and embanking of approaches to occupation bridges, permanent sidings, stations, and tool recesses.

The metalling of occupation roads.

The paving of occupation roads crossing railway on a level.

The building of Occupation Roads and Culverts.

The laying and ballasting Permanent Sidings, and the formation of Tool recesses.

The above works must be executed at the places where they may be required, and the Contractor will be paid for them according to the schedule of prices for extra works set out in the tender.

The preceding enumerated works and mode of execution are described at length in the specification of each particular work, and their forms and dimensions are represented in the accompanying drawings, which are referred to in each specification. But should any discrepancies exist between the schedule attached and

the written dimensions, or between the drawings and specification, or any ambiguity in them, the same shall be referred to the Engineer, whose decision shall be decisive; also anything contained in either the drawings or the specification, shall be equally binding to the Contractor as if it were contained in both. The written dimensions upon the drawings are to be taken in all cases in preference to the scale attached.

FENCING AND DITCHING.

The fencing described in the following Specification is of two kinds. The first Temporary, and for the prevention of trespass upon the lands adjoining the railway, during the progress, and until the completion of the works; the second, Permanent, for the enclosure of the railway when finished.

TEMPORARY FENCING.

Immediately after the delivery of any portion of the site of the intended Railway into possession of the Contractor, and previous to the commencement of the works, the Temporary Fencing shall be completed, and shall include the whole area of the land to be occupied by any of the works contained in or connected with this contract.

The Temporary Fencing shall consist of split oak Posts, placed 9 feet asunder, and 3 feet 6 inches high above the surface of the ground, morticed to receive 3 horizontal oak or larch Rails, which are also to be supported by an intermediate Stay, or prick post, firmly nailed to each of the rails.

The whole of this fencing must be firmly and substantially fixed so as to exclude sheep and all cattle from the excavations and other works, and effectually protect the adjoining lands from trespass, at all times during the progress of the works. All Drains, or alterations, or deviations in existing drains or watercourses which may be necessary for the exclusion of water from the excavations, or for the prevention of damage to the adjoining property, or any other whatever, shall be made by the Contractor, at his own expense.

PERMANENT FENCING.

The Permanent Fencing is of one description only, and as follows:—Quick fencing and ditching extending throughout the whole length of this Contract on each side of the railway, excepting the space occupied by the various bridges and

crossings of roads. This fencing is to be placed within the limits of 15 feet from the terminating slopes of the excavations and embankments. A Ditch of 6 feet wide at top, 2 feet wide at bottom, and 2 feet deep, shall be made on the higher side of the ground to be occupied by the railway. And a Ditch of 3 feet wide at top, 1 foot wide at the bottom, and 1 foot deep on the lower side of the ground. The outside of the Ditch must be 5 feet distant from the Boundary of the Land occupied by the Railway; and if the last-mentioned ditch shall be deemed insufficient in any particular case, the larger-sized ditch shall be made instead. The Material excavated from the ditch shall be used to form a mound on the space between the edge of the ditch and the Railway slope, both sides of which must be neatly faced with Turf. When the Material excavated from the ditch shall be more in quantity than sufficient to form the mound, the surplus must be conveyed to the nearest embankment. The best portion of the Vegetable Soil excavated from the ditch shall be placed in the middle of the mound, on which a double row of good 3 years old Quicks, 2 years transplanted, shall be planted, and not less than 12 Quicksets shall be contained in 1 lineal Yard.

On the inner edge of the ditch, Oak Posts and Rails must be fixed to protect the quicks. The Posts are to be of split Oak, 7 feet in length, and equal in a sectional area to a scantling of 5 inches by 3½ inches at least. They are to be placed at a distance of 9 feet from centre to centre, and to stand 3 feet 6 inches above the top of the quick mound; each post is to have three mortices completely through it, for the reception of the ends of the rails, and to be as nearly of uniform size as possible. The horizontal Rails, two in number between each pair of posts, are to be of split Oak or Larch, equal in a sectional area to a scantling of 3½ inches by 1½ inches. They are to be 10 feet in length, and the ends to be scarfed so as to fill the mortices of the posts. Midway between the Posts, an oak or larch Stay, 5 feet long, 2 inches wide, and 2 inches thick, is to be firmly nailed to each of the three horizontal rails with good tenpenny nails. The Posts must be firmly fixed in the ground, and the ends of the Rails firmly driven into the mortices in the posts, a piece of new iron hoop, 1¼ inch wide and 1-16th of an inch thick, shall be nailed round the top of every post, to prevent its splitting.

The Fencing shall be made with as few bendings as the nature of the ground will admit of, and the Ditch along the side of the mound shall descend as uniformly as possible to the nearest main drain or watercourse, by which the drainage of the adjoining lands may be effected. Such parts of the Temporary Fencing as can be made available shall be permitted to be used in the construction of the Permanent Fencing, provided the material be of the requisite strength and quality, and uninjured by previous use.

The erection of the Permanent Fencing shall proceed as rapidly as the progress of the other works and the nature of the season will admit of. At the bottom of the Embankment, small Draining Tiles must be laid through the quick mound, at intervals of not more than 20 yards, for the purpose of bringing all the water draining from the slopes of the Embankment into the fence Ditches.

Such parts of the Permanent Fencing as may be erected before the completion of the other works, shall be kept in complete order by the Contractor. The Quicksets shall be cleaned and weeded at least twice a year, and all broken posts, rails, or stays, replaced by new ones, equal in quality to those originally used. All the Quicksets which may not grow or take root must be pulled, and three-years old living quicksets, similar to those described, planted in their places.

EXCAVATIONS AND EMBANKMENTS.

The part coloured Red on the Plan, Drawing No. 2, shows the direction of the Railway, and the area of the land which will be purchased by the Railway Company, and upon which the Contractor shall have full permission to erect any temporary houses, offices, &c., necessary during the execution of the works, or any machinery for excavating or embanking, provided that such erection shall not be specially prohibited by the Act of Parliament for making the Railway.

The Embankments are coloured Green, and the Excavations Red, on the Section, Drawing No. 1. The black line on the section describes the top of the embankments, and the bottom of the Excavations, previous to the laying of the permanent way. The black undulating line describes the present Natural Surface of the ground along the centre line of the Railway, and shows the heights of the embankments and depths of the excavations, from which data their contents have been calculated, on the supposition "that the Area of any cross section in side long ground does not differ from the Area of a Section on level ground." The level and other admeasurements from which the section is made, are believed to be accurate, but the Contractor must verify the results, as he will be held liable to the consequences of any errors. Plans and Sections of an excavation and an embankment, with drains and fence, are shown on Drawing No. 19.

EMBANKMENTS.

The whole of the Embankments in the contract are to be made at a Slope of two to one, that is to say, when the base of the slope is 2 feet, its height shall be 1 foot, and the widths of the Embankment at the level of the Red line upon the

Section is to be 33 feet when turfed or soiled, neither more nor less. Each Embankment shall be carried forward uniformly, as nearly at the finished height and width as the due allowance for shrinking of material will admit of, and this allowance shall not exceed or fall short of the quantity deemed necessary from time to time by the Engineer. In all cases this must be carefully and strictly attended to, in order to avoid the necessity of making any subsequent addition either to the heights or widths of the embankments, to bring them to their proper level and dimensions.

The surface of the Embankment shall be kept in such form, or shall be intersected by such Drains or channels, as will always effectually prevent the formation of pools of water on them, and insure the embankments being kept as dry as possible during the progress of their formation. Whenever the Material turned over the end of the embankment shall not form the proper slope, it shall be carefully trimmed to its required form; and this operation shall be proceeded with at the same rate as the formation of the embankment.

As the Embankments advance and become consolidated, their sides shall be carefully trimmed into planes, or faces having the proper slope specified on the section, and the face of the slopes are then to be neatly covered with Turfs of grass, not less than 8 inches in thickness, laid with the greensward outwards. The turf must be taken from the ground to be occupied by the base of the embankments, and where the land is arable, the soil must be carefully removed from the base of the embankment, and afterwards uniformly distributed over the slopes not less than 6 inches in thickness. The Slopes which are to be thus covered with Soil or vegetable mould, are to be sown with rye-grass and clover-seed, mixed in equal quantities, and not less than 3 lbs. of the mixed Seed per acre is to be sown and equally distributed on them, as soon as the season will admit of its being properly done. When, amongst the material which is brought to and shot over the ends of the embankments, there shall be large lumps, they must, if more than 6 inches in diameter, be broken to pieces.

EXCAVATIONS.

The whole of the Excavations in this Contract must be 33 feet wide at the level of the Red line upon the Section when turfed or soiled, neither more nor less. The Slopes will be one and a half to one, that is to say, 1 foot 6 inches horizontal base to every foot of vertical height, excepting in the excavation marked No. 36 on the Section, and for a distance of 20 chains southward of Northchurch tunnel

in excavations marked No. 35, where the Slopes will be three quarters to one—that is, 9 inches horizontal base to every foot vertical height.

The Slopes of the Excavations shall be finished as the cutting advances, and they shall be neatly and uniformly trimmed or dressed to the specified inclination, as near to the face of the cutting as possible; and immediately after any part of the Slopes shall have been dressed to the proper inclination, they shall be covered with Turfs which have been previously taken from the land so excavated, in the same manner hereinbefore specified for the embankments; and where the excavations occur in such parts as are not grass land, the slopes are to be covered with Soil or vegetable mould previously procured from the site of the said excavation, and sown with rye-grass and clover-seed, as hereinbefore specified for the embankment.

In the formations of the Excavations and Embankments in this contract, the Contractor shall not remove the turf or soil from the ground for a greater distance than one statute Chain in advance of the face of the excavations or embankments, and that which has been cut must be removed back to a point where the slope is ready for receiving it, and laid down as previously directed, with as little delay as possible. Whenever and wherever springs, soaks, or streams of water may appear and issue from the face of the slopes, the Contractor shall be bound to make and maintain during the progress and until the completion of the works, such Drains or water-courses as shall completely and effectually prevent the said springs, soaks, or streams of water from injuring the Slopes, and shall convey the whole of such water into proper drains, so that none shall be permitted to lodge in the excavations; and when beds of sand and other loose material occur, the face of the slopes must be protected from the injurious effects of such springs or streams of water by such other means as may be deemed advisable or necessary by the Engineer. At the bottom of each slope, a Drain of uniform depth below the rails, as shown on Drawing No. 19, shall be made; and these Drains must be continued on both sides under the Bridges which cross the Railway; and a Drain shall be made at the top of each slope so as to exclude from the excavations any water draining off or flowing from the adjoining lands; and all covered or open Drains which may be intersected by the Excavations, must be made to discharge their water into the Ditch outside at the top of the slope, for which purpose the said Ditch shall be made as deep at least as the bottom of the lowest intersected Drains, and the Space between the ditch and the top of the slope of excavation shall be well puddled at the place of intersection. The Contractor shall be compelled to open or make any new Drain which the Engineer may deem necessary for the exclusion

of any water from the Railway excavation, or in the formation of any of the excavations or embankments. The Contractor must provide, at his own expense, all the Rails, chairs, keys, and pins, blocks and sleepers, as well as Waggons, barrows, planks, and all other machinery, materials, and utensils, which may be necessary for executing this Contract. When any Material occurs in the excavations suitable for making Bricks, the Contractor shall be at liberty to make use of that material for that purpose; but if, in so doing, he shall cause any deficiency for the formation of the embankment, he shall make up the deficiency by a Side Cutting, at his own expense, in such of the excavations as the Engineer may direct; and if such side cutting require an additional quantity of Ground, the Contractor shall indemnify the Company for the purchase of the same. Trial Shafts have been sunk in several places on the Line, for the purpose of procuring information as to the nature of the material; and their situations are marked on the Section.

GENERAL STIPULATIONS,

Which are to apply to the whole of the Bridges, Culverts, and other Works, wherein the workmanship and materials described may be used.

BRICKWORK.

The Bricks made use of shall be sound, well-shaped, thoroughly burnt, and of uniform colour on the face of the work.

No broken Bricks shall be used, except in the case hereinafter mentioned, and no joint of mortar shall exceed one-quarter of an inch in thickness. No difference of workmanship shall be allowed in the inside and outside work, except so far as hereinafter specified; and the whole of the joints shall be flushed up solid with mortar, and the outside joints neatly drawn. The Bond shall be either English or Flemish, as the Engineer shall direct.

MORTAR.

The Mortar shall consist of the best fresh burnt Dorking or other Lime, approved by the Engineer, and sharp Sand, mixed in the proportion of 3 measures of sand to 1 of lime. They must be mixed in a dry state, and well tempered, by passing through a pug mill, with a proper quantity of water.

ROMAN CEMENT.

The Roman Cement shall be of the best quality, and shall be mixed with an equal quantity of sharp sand. None shall be used which has set or become hard.

ARCHES.

Arches when of brick shall be built either in concentric half-brick Rings, or in such other manner as the Engineer may direct.

BACKING TO ARCHES.

The Backing shall consist of Brickwork laid in mortar as before described, and shall be built in every respect equal to the outside work. Bats may be used in this part of the work, but no course shall contain a greater quantity of bats than whole bricks.

WINGS AND SPANDRELS.

The Wing Walls shall be of that description of brickwork before described; they shall be built battering, as shown upon the drawings. The Spandrels will be of precisely the same description of workmanship as the wings. The bricks must be cut so as to fit the arch accurately all round.

FILLING IN OVER ARCHES.

The space between the wing walls, arch and backing of bridges, shall be filled in with hard dry material, when it can be got, well rammed down, but when it is necessary to use clay for the purpose, it shall be firmly punned down in layers of not more than 9 inches thick, until it is within 18 inches of the level of the surface of the roadway, which depth must be filled with gravel, and the roadway formed as hereinafter described under " Approaches to Bridges."

STONE IMPOSTS.

Where Stone Imposts or springing courses are used, the stones shall always be equal to the full thickness of the arch, and no stone shall be less than 2 feet 6 inches long, and when required, they shall be dowelled together.

SPRING-COURSES.

These must be of the form and dimensions shown on the drawings. No stone must be less than 2 feet 6 inches in length, and the whole to be throated underneath. All the surfaces, excepting the back, shall be fair tooled.

COPING.

To be of the form and dimensions shown on the drawings. No stone to be less than 2 feet in length, and each stone must be dowelled and leaded to the adjoining one. The coping shall be fair-tooled all over, and a throating, half an inch wide, cut on its under side.

STONE.

All Stone used for Bridges and parts of bridges throughout this contract, shall be Derbyshire Bramley Fall, or stone fully equal to it in quality, and approved by the Engineer. The String-course, Parapet wall, and Coping, shall not be put on until after the centres are struck, which shall not be done without the permission of the Engineer. All the centering must be done to the satisfaction of the Engineer. Great care must be taken that the bridges are so placed, that the outside rails when laid shall be equi-distant and parallel with the faces of the abutments or parapet walls.

EXCAVATING FOUNDATIONS.

The Contractor is to excavate for the foundations of all Bridges, Culverts, and other works, to keep out all water, place Dams, and provide all Centering planks, and tools of every description necessary for the perfect execution of his work, at his own expense, and to be included in the amount of his tender; and in case of the foundations of any of the works requiring, in the opinion of the Engineer, to be carried lower than is shown upon the drawings, the Contractor is to make such Extra excavations and do all Extra pumping, or other contingent works incident thereto, at the rate specified in the Schedule of prices. The increase to the masonry or brickwork, or other matter constituting the foundations caused by such additional depth, will be allowed as an Extra to the Contractor, according to the rate specified in his Schedule of prices.

DRAINS UNDER BRIDGES.

Drains must be constructed under all the Bridges, on each side of the Railway, 15 inches wide at the top, and 12 inches wide at the bottom; to be sunk as low as the drain at the outside of the ballasting. They will each consist of a brick wall, 14 inches thick, 3 feet deep, and equal in length to the width of the bridge, and as much more as shall be necessary to connect with the side Drains. At the outside of the ballasting, there will be two courses of bricks to form the bottom. The whole will be laid in mortar, as described for the bridges.

CONCRETE.

All Concrete must be composed of Gravel, perfectly clean, and mixed with fresh, well-burnt Lime, in the proportions of 6 parts of Gravel to 1 of Lime. The lime and gravel to be mixed in a dry state, and a sufficient quantity of water afterwards added.

BRIDGE AT THE CROSSING OF THE GRAND JUNCTION CANAL.

The Bridge crossing the Grand Junction Canal at Blisworth is very similar in design to this. Vide Plates 36, 37, 38, and 39.

The Railway intersects the Canal at an angle of 40°, and at a point where the height of the Rails above the level of the water is 29 feet 8 inches, and the depth of the Embankment 25 feet. The Railway rises in the direction of Birmingham at the rate of 1 in 330.

The Bridge will consist of six Main Ribs of cast iron, forming an arch of 66 feet span on the skew, and 11 feet 9 inches rise, and leaving a clear width of 33 feet 6 inches between the abutments, measured at right angles, to the centre line of the canal. Each of the Ribs will consist of three pieces, upon which the open work of the spandrels will be fixed. Beams of Oak will run along the top of the four middle ribs, and be bolted to them; to these beams will be attached the Railway Chairs. The spaces between the ribs will be covered with cast iron Plates, upon which the ballasting of the Railway will be laid. The Abutments and wing walls will consist of brickwork laid in mortar, excepting such parts of them as stand on the planked platform hereinafter described, which must be built in Roman Cement for the distance of 18 inches from the face up to the level of the Towing Path of the canal. The bottoms of the excavations for the founda-

tions of the abutments must be made perfectly smooth and level; and a Platform, consisting of a double thickness of Planking, and extending under every part of the base of the abutments, must be laid down. On this platform the Abutments will be raised. At the springing of the Arch, a course of Bramley Fall stone, forming the skew backs or imposts, will be built into the brickwork, and upon this will be built the brick walls. At the backs of the Main Ribs, the backing of the arch, consisting entirely of brickwork, will be carried out between the wing walls to the extent shown on the drawings. It will be supported on five small Arches, springing from walls which run parallel with the wing walls. The Wing Walls and pilasters in front of the abutments will be wholly of brick, and will be built battering. The whole of the outside of abutments and pilasters to be faced with White bricks from Cowley, or such other white bricks as may be approved of by the Engineer. A string-course of stone, as shown in the drawings, will run along the wing walls and pilasters as far as the face of the abutments, and the same form will be continued in cast iron over the arch. The Pilasters, both in front of the abutments and at the ends of the wing walls, will have plinths, facias and caps of stone. The Towing Path of the canal will be retained by a row of cast iron piles and plates running along its face and joining on the present towing path with an easy curve, as shown in drawings. The Piles will be tied back by land Ties fixed into the abutments of the bridge, or to wooden piles driven in for the purpose; the space between this row of piling and abutments will be filled with gravel and lime Concrete.

Do. . . . . . . Do. PLANKING OF PLATFORM.

The Planking shall consist of two courses of good Memel Timber, each 4 inches in thickness. The upper course must cross the lower at right angles, and be firmly spiked to it with wrought iron Spikes 7 inches long and half an inch square.

Do. . . . . . . Do. ABUTMENTS.

The bottom of the brickwork of the Abutments shall be laid 6 feet below the water level of the Canal, and 8 feet below that of the Towing Path; they will consist of brickwork laid in mortar, as hereinbefore described, excepting for the depth of 18 inches from each of the faces, and up to the level of the Towing Path, which will be laid in Roman cement. The Walls which carry the small arches supporting the backing shall be founded at the depth of 3 feet below the water level of the canal; they shall be 2 feet in thickness, and uniformly carried

up to the springing of the cross arches; these Arches are of different spans, and spring at different heights, so as to keep the level at the crown the same in each; they are to be 9 inches in thickness; and the backing is to be 4 feet in thickness above the estrados of the cross arches last mentioned. The Walls at the back of the cast iron ribs shall be 3 feet in thickness, and carried up to the level of the top of the ribs; they shall consist entirely of brickwork. The Skew-backs or Imposts shall be of Bramley Fall stone, of the shape and dimensions shown on the drawing and each Stone shall be cramped to the adjoining one with wrought iron cramps run in with lead, 12 inches long, 2 inches wide, and ¾ of an inch thick. The fronts and the beds of the stones are to be fairly dressed, and the backs only to be left rough.

Do. . . . . . . Do. WING WALLS.

The Wing Walls shall consist of brickwork laid in mortar, and must be built up to the string-course with a batter of 1 inch to a foot. Counterforts, 3 feet wide, 3 feet in thickness, and about 11 feet apart, must be built at the back of the wing walls, and well bonded into the substance of the walls.

Do. . . . . . . Do. STONE STRING COURSE.

A String-course of Bramley Fall stone, dressed into a torus moulding, must be set on the wing walls and abutments, at the height shown in the drawings. The average length of the stones must be 4 feet, and whenever any stone falls short of this dimension, the next shall exceed it as much as the former is below it, and no stone shall be less than 3 feet in length; the whole must be neatly dressed, and the beds and cross joints made perfectly true and close.

Do. . . . . . . Do. STONE PLINTHS, FACIAS AND CAPS TO THE PILASTERS.

The stone Plinths and Facias must project 2 inches from the face of the brickwork, and shall be bedded in the work not less than 6 inches. The Caps to the pilasters must be 9 inches thick on the face and 1 foot in the middle, and must in no case consist of more than one stone. The whole of the outer surfaces are to be fair-tooled.

Do. . . . . . . Do. CAST IRON RIBS.

Each cast iron Rib will be a segment of a circle of 66 feet span and 11 feet 9 inches rise; 2 feet deep at the crown, and 2 feet 9 inches at the springing. The thickness of the metal of the middle part must be 2 inches, and that of moulding at top and bottom 6 inches. Each rib is to be cast in three pieces, and they will be bolted together through the flanges cast on them for that purpose, with bolts 2 inches in diameter. The Open work in the spandrels must be cast separate, (excepting so far on each side of the arch as is pointed out by the letters A, A, Drawing No. 5, Fig. 1, which will be cast on the centre piece of the main rib,) and keyed into sockets cast on the ribs for that purpose, as shown on the drawings. Sockets must be cast on the ribs to receive the ends of the longitudinal and diagonal Braces, and to admit of their being firmly keyed to them, (see Drawing) and holes must also be formed at the proper places to allow a wrought iron Tie to extend from one side to the other of the bridge. All the bolt Holes which go through the outside ribs must be counter sunk. The Top Tables of each of the Ribs on which the oak timbers hereinbefore mentioned rest, must have bolt holes 1 inch in diameter cast in them, at a distance of 3 feet, centre and centre, alternately, on opposite sides of the beam, in order to secure the said timbers. They must also have bolt holes cast ¾ of an inch in diameter, suitable for bolting the roadway plates.

Do. . . . . . . Do. SKEW BACK PLATES.

The Ribs will spring from cast iron plates 2 inches in thickness, cast in two pieces and bolted together with four 2 inch iron bolts. The parts where the main ribs spring must be so recessed as to present faces at right angles to the direction of the ribs, which must be also keyed into their places with wrought iron wedges. The stone Skew-backs must be worked to fit exactly the various bendings of the plates, and where they join they must be let into the stone work. The whole must be firmly and solidly bedded, and run with Roman cement.

Do. . . . . . . Do. CROSS BRACES AND TIES.

Between the main ribs, and diagonally across the arch, are cast iron Braces, as shown on Drawing No. 4. They are cast with palms to admit of their being wedged into the sockets cast on the ribs. Wrought iron Tie bolts run across the

arch at a direction parallel with the abutments. They are contained in cast iron pipes, the sides of which are feathered, and the ends furnished with palms, in order that they may be wedged into sockets cast on the ribs. The greatest care will be required in the fitting of these braces and ties, in order that they may not be subject to unequal or twisting strains.

Do. . . . . . . Do. TORUS MOULDING AND PLINTH OVER ARCH.

This moulding and plinth must be of cast iron. It must be cast in several pieces, which are to be bolted together with four 1 inch bolts; and sockets must also be cast in it for the reception of the standards of the iron railing, which are to be fastened with keys as shown on the drawing. The Back plates, or that part next the railway, must be cast separate, in order to give access to the bolts which form the fastenings to the main front rib. They must be afterwards screwed on, and the joints so arranged as to come intermediately between the joint moulding and plinth.

Do. . . . . . . Do. IRON RAILING.

The whole of the distance between the pilasters and the abutments, and between them and the piers at the end of the wing walls, is to be occupied by Iron Railing, as shown in the Drawings. It is to be cast in lengths corresponding with those of the moulding and plinth, into the sockets of which, as before mentioned, it must be firmly fixed with wrought iron keys. Each length of railing must join to the next with a neat half-lap joint, and its middle standard must be steadied by having a cast iron knee or bracket screwed to it, as shown on the drawings.

That portion of railing between the pilasters and piers, at the end of the wing walls, must be secured to the stone plinth, by being run in with lead, the knees or brackets being attached as before described. The ends of the railing must run into the pilasters for the length of 3 inches, and either be secured there or left loose as the Engineer may direct. All the Castings must be of No. 1 iron, excepting the roadway Plates, which may be of No. 3; and no open sand casts will be allowed, excepting for roadway plates. All the malleable iron used in this work must be of the best scrap iron; a thickness of patent felt covered with white lead, to be placed between all the joints of the iron work. All the iron work must be painted with two coats of paint.

Do. . . . . . . Do. OAK BEAMS.

An English oak Beam of the dimensions shown in the drawings must be bolted on each of the four middle Ribs with bolts 1 inch square, 3 feet distant, centre to centre, so arranged as to be on opposite sides of the centre beams. The length of each oak Beam must be equal to that of the Rib, together with the thickness of the wall at the back of the ribs: they must be cut away to fit the road Plates, and their bolt heads, and so as to secure a firm and solid fitting upon the tops of the ribs. The Chairs must be secured to the beams, each with two wrought iron bolts ¾ of an inch in diameter, screwed into nuts let into the substance of the beams. None of the beams shall be made in less than two pieces, and these shall be of equal length, and joined with a Scarf 2 feet long.

Do. . . . . . . Do. FILLING IN BETWEEN WING WALLS.

The ends of the embankments shall not be brought by means of waggons nearer than 20 yards to the extremity of the wing walls, and the remainder of the earth necessary to complete the embankment shall be wheeled in barrows. The filling in between and around the wing walls shall be well punned in layers of not more than 9 inches thick, as the brickwork is brought up, so as to be firm and solid.

Do. . . . . . . Do. BALLASTING ROADWAY.

The whole surface of the Bridge shall be covered with a stratum of clean Gravel, perfectly free from earthy matter. That part of the Bridge over the arch, up to a level of 2 inches beneath the surface of the Rails, and the remainder of the bridge to be covered to the depth of 2 feet 4 inches beneath the same level, as hereinafter directed in the description of laying the permanent way.

Do. . . . . . . Do. INCLINATION OF RAILWAY.

The Railway over the Bridge will have an inclination of 1 foot in 330 feet, and the whole work must be erected as much out of the level as that quantity.

Do. . . . . . . Do. CAST IRON PILING FOR TOWING PATH.

The Towing Path of the Canal is retained by a row of cast iron piling to the extent shown on the drawings. The piling is to consist of Main Piles and Plates,

the form and dimensions of which are represented on the drawing. The Main Piles are to be driven to the distance of 6 feet 5 from centre to centre, perfectly upright, and exactly equi-distant from each other at top and bottom; they are then to be tied back by wrought iron Ties, $1\frac{1}{2}$ inch in diameter, in the manner shown in the drawings.

The ground having been cleared away between these piles, the cast iron Plates are to be dropped into the grooves in the main piles, and the whole being secured at top by the capping being firmly bolted on. The Tie bolts mentioned above are to be secured to stones built into the abutments, or to needle Piles, consisting of whole timbers, 12 inches square, and driven to the depth of 8 feet below the surface of the ground. At the ends of the Piling, and to the extent shown on the drawing, brick walls are to be built; and they are to be 3 feet thick at the bottom and 2 feet 3 inches at the top, and must return for a depth of 18 inches at the points where they join the piling and the present towing path.

Do. . . . . . . Do. COFFER DAMS.

In removing the Coffer Dams which may be necessary in putting in the foundations of the bridge, the sheet piles must be cut off level with the bottom of the canal.

In explanation of the restrictions to which the Contractor will be liable in regard to any interference with the navigation of the Canal which he may disturb in laying the foundations of this bridge, by driving coffer dams or otherwise, the following quotations from the Act of Parliament are subjoined:—

> "And the said Railway Company shall, and they are hereby required, "during the progress of constructing each such bridge over the said Grand "Junction Canal, and of the necessary repairs or renewal thereof from time "to time, and at all times, to leave an open and uninterrupted Navigable "water way in such Canal, of not less than 16 feet, during the time of con-"structing and putting the foundation walls of the abutments of each of the "said bridges, and of the new towing path of the same, up to 1 foot above "the top water level of the said canal, and which time of contracting the "water way shall not exceed thirty days; nor shall less than 22 feet for the "said water way, and 8 feet for the said towing path, be left during the con-"struction or repairing or renewing each such bridge; and the present "Towing Path shall remain undisturbed until the new towing path wall shall "be erected, and the ground made good and properly gravelled, and open "for the free passage for horses under each such bridge."

The Contractor shall be required to fix the whole of the Iron work of the bridge upon his own premises, for the inspection of the Engineer, and no part to be removed until he receives a written order to that effect. In this case, as in any other case, (in accordance to the general clause to that effect hereinbefore mentioned,) the Engineer shall have the power to make any alterations, deductions, or additions he may see fit.

BRIDGE AT THE CROSSING OF THE ROAD FROM BOURNE END TO POUCHING END.

Vide Plate 18.

This Bridge passes under the Railway at a point where the depth of the embankment is 24 feet 9 inches, and the level of the rails is 27 feet 1 inch above the present surface of the road. The Arch is a semicircle of 7 feet 6 inches radius and 1 foot 6 inches thickness; and the height of the springing from the level of the road is 15 feet 6 inches. The clear width between the parapets is 28 feet. This Bridge is to be built of brick, with the exception of the string-courses, copings, and caps to the pilasters, which are to be of stone. Counterforts are to be built behind the Abutments, and Arches turned between them in the manner shown in the drawings. For Materials and Workmanship, see General Stipulations hereinbefore given.

BRIDGE AT THE CROSSING OF THE HAXTER'S END ROAD.

Vide Plate 19.

This Bridge passes over the Railway at a point where it is level with the present road. The bridge is to be of brick, except the string-course, coping, and imposts, which are to be of stone. The Arch is a semi-ellipse, 30 feet span, and 9 feet rise; the height from the rails to the crown of the arch is 17 feet, and the clear width between the parapets is 15 feet. The Inclination of the roadway must be at the uniform rate of 1 in 13. The Slopes of the approaches are 2 to 1 at right angles to the road, but they must be reduced to 1½ to 1 along the face of the wing walls. The Approaches to the bridge are shown on the drawings. For particulars of Materials and Workmanship, see general directions hereinbefore given.

BRIDGE AT THE CROSSING OF THE ROAD FROM BERKHAMPSTEAD TO GREAT GADDESDEN.

Vide Plate 20.

This Bridge passes over the Railway at a point where the Embankment is 4 feet 4 inches deep, or where the level of the rails is 6 feet 8 inches above the present surface of the ground. It is to be built of brick, excepting the string-courses, imposts, coping, and caps to the pilasters, which are to be of stone. The Arch is a semi-ellipse of 30 feet span, and 10 feet rise, and 1 foot $10\frac{1}{2}$ inches thick. The height from the level of the rails to the crown of the arch is 17 feet, and the clear width between the Parapets is 15 feet. The Wing Walls run nearly parallel with the Railway, and are returned with a short wall at the ends, as shown in the drawings. The Approaches to the bridge are shown in the drawings. For particulars respecting Materials and Workmanship, see General Stipulations hereinbefore given.

BRIDGE AT THE CROSSING OF THE ROAD FROM BERKHAMPSTEAD TO GREAT GADDESDEN,

This Road crosses the Railway at a point where the depth of the cutting is 24 feet, measure at the centre line. The Bridge is to be of brick, excepting the imposts, string-courses, and coping, which are to be of stone. The string-course is to be 9 inches deep on the face, to project 3 inches, and to be built into the brickwork $4\frac{1}{2}$ inches. The coping must be 6 inches deep in the middle, the top and upper corners must be neatly rounded off, and it must project 3 inches from the face on each side. A throating 2 inches deep must be cut on both string-course and copings on the underside, throughout their length. The arch is a semi-ellipse of 30 feet span, and 8 feet rise, and the thickness is 1 foot $10\frac{1}{2}$ inches. The height, on the level of the Rails to the crown of the arch, is 17 feet 8 inches, and the clear width between the parapets is 15 feet. The surface of the Road is inclined at the rate of 1 foot in 8 feet. This inclination must be kept as it is, and the parapet of the bridge built parallel to it. The form and dimensions are shown in the drawing. For particulars of Workmanship and Materials, see General Stipulations hereinbefore given.

BRIDGE AT THE CROSSING OF THE ROAD FROM BERKHAMPSTEAD TO BERKHAMPSTEAD PLACE.

Vide Plate 40.

This road passes the Railway at an angle of 45 degrees, and at a point where the depth of the embankment is 13 feet 6 inches, or where the surface of the rails is 13 feet 10 inches above the surface of the present road. The Bridge consists of six cast iron Girders, or Ribs, resting on a course of stone built into the abutment walls; those on the outside, and supporting the parapet walls, are 2 feet 6 inches deep; and those inside, carrying the Railway, are 2 feet 3 inches in depth, with top and bottom Tables, the former 10 inches, and the latter 1 foot 6 inches broad; the thickness of the iron throughout is 2 inches. Three pairs of wrought iron Ties, $1\frac{1}{4}$ inch in diameter, must pass through each of the outside ribs, and attach it firmly to the adjoining inside rib, in the manner shown on the drawing. The holes in the face must be countersunk, and bosses must be cast on the inside, so as not to decrease the material at those particular points. A 2-inch plank of Oak extends along the top of the four inside ribs, and on this rest the railway Chairs, which must be bolted through the wood to the table of the Rib. Brick Arches, 9 inches thick, are to be turned between the ribs, in the manner shown on the drawing, and the Spandrel Walls must be built across the Bridge at right angles with the face, and carried up to a height level with the top of the ribs. A stone string-course, dressed into a torus moulding, runs along the bridge as far as the outside of the pilasters, in the front of the abutments: it must be attached to the ribs by iron plugs, leaded into the stone, and keyed under the table of the rib. The width on the square, between the Abutments, is 15 feet, and the clear headway under the ribs must be 15 feet also; but in order to obtain this height, the road must be lowered to the extent of 1 foot 9 inches under the bridge, and it must rise at the gradual inclination of 1 in 20 to the present surface on each side. The Ribs must be of No. 1 iron, and the wrought iron bolts &c. must be of the best scrap iron.

The Contractor must be at the expense of subjecting the whole of the iron work to any test which the Engineer may think proper to apply, in order to ascertain its strength and soundness; and if any defect shall appear, the Contractor shall replace the defective casting, or iron work, for others free from such objection. For particulars of Workmanship, and material, diverting, lowering, and metalling the road, see approaches to bridges and General stipulations.

RETAINING WALL AT BERKHAMPSTEAD CASTLE.

This Wall is for the purpose of retaining the Railway Embankments along the part of the road from Berkhampstead to Berkhampstead place, immediately in front of the Castle. Pilasters are to break forward half a brick from the face of the wall, at a distance of 20 feet, as near as may be, centre to centre, and they are to run flush into the plinth at the bottom, which must project half a brick. The top course of the Plinth must consist entirely of headers, neatly bevelled off, and laid in cement. A piece of stone, of the dimensions and form shown, is to stand out as a string-course from the pilasters, and in the manner shown in the drawings, and along the wall, at the same level, a half brick projection of equal depth is to be continued, the bricks of which must be rubbed on the outer surface. Where the road passes under the Railway, this arrangement is altered, as will be seen from the drawings. A torous moulding extending as far as the outside of the pilasters in front of the abutments. Immediately behind the pilaster, the wall must be broken by counterforts, of the form and dimensions shown in the drawings, and they must be well bonded into its substance. The footings are to be carried down 1 foot 6 inches below the present surface, and whatever is the section of the ground, they must in no part be formed at a less depth. The wall is finished at each end by a curved return, and along the top of the whole extends a stone Coping, 6 inches in depth. No Stone must be less than 3 feet in length, and each stone must be secured to the adjoining one with a wrought iron cramp, 8 inches long, turned down at the ends 2 inches, and run with lead. The length of the walls, between the commencement of the return walls at each end, is 555 feet 6 inches, and the length of the return walls is 42 feet 6 inches, making the total length of the wall 640 feet 6 inches. In bringing up the Embankment, the earth must be well rammed in layers of not more than 1 foot thick, for a distance of at least 6 feet from the back of the wall. The whole of this wall must be neatly finished, and the joints drawn, and if they are acted upon by the frost before the mortar has become hard, they must be repointed in the ensuing Spring. Care must be also taken to give the wall a proper and even curvature, so that it shall be in every part parallel with the centre line of the Railway.

DIVERSION OF ROAD INTO BOURNE END ROAD.

This Road is to be diverted between the letters A and B, a distance of about $19\frac{1}{2}$ chains. The diversion must follow the direction of the railway embankment

at the outside of the ditch. The gravelling of the road must in no part be of less width than 15 feet, and a Fence and Ditch, similar to those specified for the Railway, must be formed along the further side of the road, joining neatly at the ends with the present fences. See Specification of Approaches to Bridges.

NORTHCHURCH TUNNEL.

Vide Plates 27, 28, 29, and 30.

This Tunnel commences in the field marked 34 on the plan, and terminates in that marked 38, being about 16 chains in length. The Contractor is to confine his operations to the width of 1 statute Chain, upon the surface of the ground over the intended tunnel; and previous to commencing any part of the said tunnel, the above width is to be fenced in with Temporary Fencing, similar to that hereinbefore described, which must be made to unite with the fencing along the line of Railway. This fencing is to be removed after the completion of the tunnel, and no other fencing erected, excepting over the ends, where Permanent Fencing (similar to that hereinbefore described) must be erected for the sides of the Railway. This tunnel is to consist of a brick Arch, of the form shown in the drawings, (vide Plate 29,) supported by carved Side Walls, standing upon stone skew backs, which are to be bedded upon the counter or Inverted Arch, forming the base of the tunnel: this part is to be one and a half brick in thickness, excepting the shaft, as shown on next drawing, and the arch and side walls are to be two bricks thick throughout the whole length of the tunnel, excepting for a length of 7 feet 3 inches at the front, and at a distance of 12 feet on each side of the shaft, together with the shaft length, where they will be three bricks thick, or in such other places as the Engineer may think it requisite to make them thicker; in which latter case the Contractor shall be paid for the increase according to the rate mentioned in his Schedule of Prices. The Arch, if of the thickness of one and a half brick, shall consist of three half brick rings; if it be two bricks thick, it shall consist of four and a half brick rings, and so on, and each ring shall contain five courses of bricks more than the ring immediately beneath it.

The bricks to be made use of in that part of the arch between the points C and D, Drawing No. 17, Fig. 2, are to be moulded tapers, so that the sides may radiate agreeably to the curvature for that distance. All the rest of the bricks may be of the ordinary shape. The whole of the Brickwork is to be set in mortar, excepting that part on each side of the shaft which is marked on the Drawing No. 17 to be set in Roman cement; but if the Engineer should think it necessary

to have any other portion of it set in cement, the Contractor shall be paid for the difference of cost according to the rate set forth in his Schedule of Prices. The lôngitudinal courses of brickwork must be laid perfectly straight in the direction of the tunnel, and must be parallel in every direction with the surface of the rails; and if at any time the regular continuity of the brickwork of the tunnel shall be destroyed, either in consequence of irregular shrinking, or settlement of the arch, or imperfection of the centres, the Contractor shall amend or remove such irregularity in a satisfactory manner. The stone Skew backs of the side walls, (next the invert) shall consist of stone of the quality hereinbefore described. No stone must be used less than 3 feet in length. There must be a bed of brickwork under the stone skew back, extending to the inverted arch, in which the stone work shall be soundly bedded.

Do. . . . . . . Do. - SHAFTS.

Vide Plates, 29 and 30.

The Contractor may sink two working Shafts on the centre line of the tunnel, at such places as the Engineer shall direct. They shall be 9 feet diameter inside the brickwork, and the brickwork shall be of the thickness of one brick's length. The Shafts shall be the same diameter from top to bottom, perfectly cylindrical, free from bulges and all other imperfections. The brickwork shall rest upon a cast iron Curb, fitting into the crown of the arch of the tunnel, forming a level base for the shaft to rest upon; the Bond shall be of whatever description the Engineer may require. The shafts shall be carried up to a level of 10 feet above the level of the surface, and finished with a coping of Bramley fall stone, 9 inches thick, and 15 inches long; and the stones shall be dowelled together, and run in with lead, and the dowels shall not be less than 4 inches long. Whenever any Water may occur in sinking the shafts, it must be excluded from it by a lining of Puddle behind the brickwork, or by setting the brickwork in Roman cement, or both, if necessary. The Contractor must also sink two other shafts on the centre line of the tunnel, one at each end of it, and drive a Heading, 4 feet wide and 5 feet high, the whole length of the tunnel. This Heading must be carried through, before any part of the main tunnel is commenced, and must be supported and kept open during the execution of the whole work, by timbering or such other means as may be deemed necessary by the Engineer. The Contractor will be at liberty to sink whatever Air shafts he may think proper, provided they in no case come within 50 yards of the working shaft. They are to be 3 feet diameter within the brickwork, and supported at their intersection with the arch of the tunnel on cast iron

curbs. The specification for the working Shaft, in regard both to these curbs and other workmanship and materials, must be equally applicable to these shafts. A brick Drain, as shown upon drawing, must be constructed throughout the whole length of the tunnel. The brickwork is to be laid in mortar, as hereinbefore described.

Do. . . . . . . Do. EXCAVATING.

In excavating the Tunnel, the Contractor shall not in any length advance beyond the completed brickwork more than 6 feet, without the special permission of the Engineer; and should the nature of the ground render it unsafe or inexpedient at any time to advance so much as 6 feet with the excavation beyond the brickwork, the Contractor shall limit such advances, as may be directed by the Engineer. The space excavated in advance of the brickwork shall be carefully and substantially supported by the usual modes of timbering—namely, sill props, or shores, bars, and polling boards.* The dimensions and arrangement of such timbering to be approved of by the Engineer. The invert sides, and the roof, must be cut out as nearly as possible of the finished size of the exterior of the brickwork; and in any case where the bottom may have been taken out beyond the stipulated dimensions, the excess must be made perfectly sound and good, before the brickwork of the invert is commenced, by being well filled up with suitable material. Wherever any space exists between the exterior of the brickwork and excavation, whether on the sides of the roof, arising either from the required size of the excavation being exceeded, or whether from the withdrawal of the Bars, the greatest care shall be taken to form the same perfectly solid, with suitable materials, as the brickwork advances in height, and in no case shall the brickwork rise more than two courses without this operation being effectually performed.

When the bricklayers are getting in the Side Walls, and turning in the arch, one Labourer at each face must always be employed by the Contractor to do nothing else but to pack the brickwork, by ramming in small Chalk behind the walls with an iron Rammer; and in case the Contractor should neglect or refuse to employ a man at each face for that purpose only, the Engineer shall have power to do so, and to charge the Contractor with the expense. In the upper portion of the arch, where the Bars cannot be drawn, or the operation of packing performed, until the brickwork is completed, the operation shall be proceeded with as soon as the succeeding length of excavation shall have advanced so far as to admit of its

* The Tunnel was worked similar to the Primrose Hill Tunnel, (vide Plates 15 and 16.)

being soundly and effectually performed from the end, by beaters of a suitable construction; and should the nature of the material through which the Tunnel may at any time be advancing, be so unsound as to render the drawing of the bars and planking likely to affect or disturb the brickwork, either in its form or stability, such portions of the said Bars and Planking shall be left as deemed necessary by the Engineer. None of the Sills made use of, excepting those in the first length in the shaft, shall be allowed to penetrate into or rest upon the brickwork in the Side Walls, but shall be supported by means of Tressels resting upon the invert, and quite independent of the side walls.

The holes formed by the Sills in the said first lengths shall be made good with brickwork laid in Roman cement, immediately on the sills being withdrawn. In the executing of this, and in every other part of the Contract, the Contractor must find all the Materials and Machinery for executing the works; make all the necessary Shafts, bore holes, and perform every operation necessary for completing the work in the manner intended by the Specification. All the machinery, centering, &c. must be constructed to the satisfaction of the Engineer. The material excavated from this tunnel must be conveyed to form the embankments in this Contract. Marks or signals will be given to the Contractor by the Company's Engineers, for the purpose of regulating and directing the level of the tunnel; and the Contractor shall be at the expense of erecting any temporary or permanent Marks or signals which may be considered necessary for giving the direction and levels with the requisite accuracy.

Do. . . . . . . Do. IRON CURBS TO SHAFTS.

Vide Plates 29 and 30.

The cast iron of the Curbs must be of the best No. 2 iron, the casting free from air bubbles and perfectly sound, and the bolts and nuts must be of the best scrap iron.

Do. . . . . . . Do. TUNNEL FRONTS.

The two fronts of this Tunnel are not of similar design, as shown upon the drawings.

North Front.—The Arch of the Tunnel ends in stone quoins 2 feet deep on the face, and toothing into brickwork alternately 2 feet and 4 feet 6 inches; they project from the face to the extent of 3 inches. The Arises or corners thus formed must be neatly chamfered, and great care must be taken to make the joints close and accurate, without flushing or flaw of any kind. Pilasters of solid

brickwork faced with stone, break forward from the general front on each side of the arch. They are crowned with caps of stone, and the same form of moulding is carried on between the pilasters, and also on the tops of the side walls. The arch and pilasters are surmounted by a frieze cornice and blocking course. On the pilasters, the Frieze will be of brick, faced with stone to the depth of 1 foot 6 inches and 2 feet 3 inches alternately, whilst that over the arch will be entirely of brick. The Cornice will be of solid stone throughout, and all the mouldings cut sharp and clean. The blocking Course over the arch will consist of stone, whilst that over the pilasters will be of brick, faced as before mentioned with stone. It must also be closed in at the top, the joints of which must be laid in Roman cement, so as to completely exclude water. The whole of the stone work must be fairtooled, and the joints made true and accurate. A brick Drain runs along the back of the tunnel front, and connects with other drains down the slopes of the cutting, as shown in drawing. This Drain is to consist of 9-inch brickwork, laid in Roman cement, and it must be bedded in a mass of concrete, of the extent shown on the drawing.

South Front (vide Plates 27 and 28.) The Specification for the tunnel Front just described, must be considered equally applicable to this in everything which is common to both. The Arch of the tunnel ends into stone quoins, which tooth into brickwork, alternately 2 feet 6 and 3 feet 6 inches. The whole front is faced with stone, excepting the side walls, and a part of the parapet or frieze over arch, which are of brick. The Pilasters batter on the face, as shown on the drawing, and the side walls batter at the same rate, being set back 9 inches. A Drain, as previously described, laid in cement, and bedded in concrete, runs along the foot of the slope, behind the tunnel front, and connects with other drains down the slopes of the excavation. In these fronts, wherever the brickwork appears, it must be faced with white Cowley bricks.

APPROACHES TO BRIDGES.

The Embankments forming the Approaches to the bridges, are to be made of the surplus material from the excavations on the line, should such exist. Should there be no surplus material, then the requisite quantity for any approach must be obtained by altering the slopes of one or more of the excavations on the line of Railway. The Approaches must be made of such height and inclinations as shown in the section of approaches to each bridge. The width of the top of the approach shall be six feet more than the width of each bridge within the parapets. The embankments must be formed in the same manner as directed in the specifica-

tion of the embankments on the line of Railway. The surface of the Embankments when formed, shall be made regular and even, and be well beaten with heavy beaters, and covered with a casing of good Gravel, 10 inches in thickness in the middle part of the road, and 6 inches on each side; the best portion of the gravel must be placed in 9 feet of the middle part of the road. The ruts must be filled up from time to time, and the surface kept smooth and even. The whole of the embankments, from either termination up to the parapet walls of the bridges, must be protected on both sides by wood posts and rails, as shown on drawings. The wood Posts must be of good oak, free from sap, and straight grained. The Rails, and so much of the posts as is seen above the ground, shall be sawn out square, neatly planed, and painted with two coats of stone-coloured paint; all the joints must be made with white lead, and all the wood beneath the surface of the ground to be neatly charred. A ditch, with railing and quick fence, similar to that hereinbefore described, for the tops of the excavations and bottoms of the embankments upon the line of Railway, must be made on each side of the line of embankments of each approach, and they must be made to join the fence of the Railway. Previous to any of the works connected with any of the bridges, approaches to bridges, approaches to paved crossing, or diversions of roads, which may in any way affect existing roads, being begun, a good and well made Temporary Road shall be provided and maintained, for the free and uninterrupted passage of carriages of every description. Every precaution must be taken by the Contractor during the alteration of any of the roads to erect proper fencing, and fix lights, as the Company will not be held liable for any injury which may ensue from neglect of these precautions. The Contractor must make any alterations necessary in the direction of the roads, for the convenient approach to all bridges specified in this contract.

BALLASTING AND LAYING THE PERMANENT WAY.

Vide Plate 1.

The Railway is intended to form a double way, composed of four single lines of Rails, and will ascend in the direction of Birmingham at the uniform rate of 1 in 330, throughout the whole length of this contract. The greatest care will be required that the portions shown on the Plan, Drawing No. 2, as straight, shall be perfectly so, and that the Curves are all uniform and properly brought into the straight lines. The laying and ballasting the Permanent Way is intended to be completed in such portions, and at such times, as will meet the convenience of the Contractor in executing the other works. Previous to the delivery of the

materials of the permanent way to the Contractor, the surfaces of the embankments, and the bottoms of the excavations, shall be made the proper heights and depth, and uniform in width, level, or inclination; and they shall be completely drained, and certified by the Engineer as being in a fit state to receive the permanent ballasting. The Materials to be delivered to the Contractor, shall consist of Rails, chairs, keys, pins, blocks, sleepers, and oak trenails; and he will be held responsible for the re-placement, in case of loss or injury, of the materials thus delivered to him, from the time of their delivery to the expiration of his contract. The rails, chairs, keys, pins, blocks, sleepers, and trenails, will be delivered on any wharf, or landing place, upon the line of the Grand Junction Canal which may be made choice of by the Contractor; but the Contractor is to pay the wharfage, and other incidental charges, and also the expense of conveyance from the wharf, or landing place, to the line of Railway.

The Rails will be in lengths of from 12 to 18 feet, and weigh 50lbs. per lineal yard. They will be supported every yard by a cast iron Chair, or pedestal, which will weigh about 20lbs., and be accompanied by two wrought iron keys for fixing the rail into the chair, and two pins for fixing the chair upon the block or sleeper. The Sleepers will be of wood, the dimensions of each part, and the construction of the whole, are shown upon the drawing. The Company will reserve to themselves the right of directing whether stone blocks or wood sleepers shall be used, or both, and if both, in what proportion and situation. The material for Ballasting shall be composed of broken stone, or clean gravel, entirely free from any admixture of clay, capable of setting hard, and not retentive of moisture. If broken stone be used, none shall be larger than cubes of 2 inches. The Ballasting shall be spread over the whole surface of the top of the embankment, and bottoms of excavations, between the drains, and an uniform thickness of 10 inches where stone blocks are employed, and 18 inches where wood sleepers are used. This stratum of Ballast shall be beaten into a firm and solid mass, by heavy beaters, worked by at least two men, and the thickness before mentioned shall be considered to apply only after this operation has been effectually performed. Upon this surface the blocks and sleepers are to be laid in their proper situations for receiving the rails.

When stone blocks are employed, each block shall be bedded in its proper situation, by frequently lifting it by a spring lever to the height of 1 foot above the surface, and letting it fall forcibly on the ballasting; this operation shall be continued until no sensible difference of level is perceived after each fall: should the block then be found too low, it shall be removed out, and more material placed in its intended bed, and the same operation continued until the block has reached

its proper level, and has obtained as firm and uniform a bed as can be obtained throughout the whole area of the under side of the block. When wooden Sleepers are employed, the ballasting for the intended bed shall be beaten by heavy beaters, and each sleeper also forcibly beaten when it has been placed in its position, until it has been firmly and uniformly bedded throughout its whole length, and reached its proper level. If it be found lower than required, it shall be removed, and additional materials placed under its bed: the same process as before must then be renewed until it has reached its proper level. The Rails must be laid at their proper level, each of them parallel to each other, and at the same height at any point. The joinings must be made perfectly even, whether square, half-lapped, or scarfed, and be firmly secured in the chairs. The two lines of way to be 6 feet apart, and the width between the inside of the rails 4 feet $8\frac{1}{2}$ inches.

The Stone Blocks will be delivered to the Contractor in a rough state, and he will be required to drill two cylindrical holes in each block, 6 inches deep, and $2\frac{1}{4}$ inches in diameter; to make the upper surface of each block perfectly level; to drive the oak trenails, and cut off their tops flush with the surface of the block; and to fix the chair firmly in its proper position, by means of the iron pins furnished to him for that purpose. The wood Sleepers will be delivered to the Contractor as sawn out, and he will be required to make their upper surfaces perfectly level for the reception of the chair, which must be firmly fixed in to the exact guage. The pins shall not be driven into the sleepers without the holes having been previously bored with a proper sized auger. The Rails must be securely fixed into the chairs, by means of two keys. The Chairs shall be firmly fixed on the sleepers or blocks. The whole of the upper surfaces of the stone blocks must be worked to a plain surface, and a space in the centre, of sufficient size for the whole bed of the chair, must be fairtooled perfectly level, so that the chair will rest perfectly steady upon the block. Any of the Rails which may be twisted or bent in the least degree, to be made perfectly straight with proper hammers and anvils, previous to their being laid down. Should any Gravel, or any other suitable material, occur in any of the excavations included in this contract, the Contractor shall be at liberty to use the same; but if in so doing he shall cause any deficiency in the material for the formation of the embankments, he shall make up the deficiency by a side Cutting, in such of the excavations as the Engineer may point out, and at his own expense. If such side Cutting shall require an additional quantity of land, the Contractor shall indemnify the Company for the expense of purchasing the same.

The Contractor shall in no case remove any material from the intended sites of any of the embankments, unless permitted by the Engineer. The Contractor

shall also be at the whole expense of purchasing and obtaining gravel, or stones, for the purpose of Ballasting, whether brought from the adjoining lands or otherwise. Brick Drains, throughout the excavations, are to be laid in the ballasting, as shown on the drawing. One Drain shall be laid in the centre of the ballasting, throughout the whole length of the excavations, and shall have Cross Drains, at intervals of every 5 yards, communicating with the Open drains outside the ballasting, on either side alternately. They must be properly and securely laid with good bricks, without mortar, but 18 inches in length at the open ends, and shall be laid in Roman cement.

The Contractor shall give the Assistant Engineer a receipt, stating the number of rails, or other materials, in each parcel delivered to him, and after they are placed in his possession, he shall be accountable for the loss of any part of them. He shall also replace any rails, chairs, keys, pins, trenails, blocks, and sleepers, which may have been broken, or otherwise rendered unfit for use, while in his possession. The Contractor shall be permitted to make Sidings or crossings from one line of the permanent way to the other, for his own convenience, during the progress of the works, provided he does not injure the rails in so doing, and removes them when the works are completed. No Waggons, carriages, or engines, employed by the Contractor on the permanent road, shall have a greater weight placed on any one axle than 3 tons, unless the carriages or engines are placed on good and sufficient springs; and when they are so mounted, the weight on any one axle shall not exceed 4 tons.

EXTRA OR CONTINGENT WORKS.

FENCE GATES.

The Fence Gates are to be made of the form and dimensions shown in the drawing. The heels and ends are to be of good oak, sawn out the proper dimensions, and morticed for the reception of the horizontal bars. The horizontal Bars are to be five in number, of cleft oak, and smoothed over. The ends must fit the mortices of the heels and heads, and be secured by oak pins. The diagonal Braces will be similar to the bars, and firmly nailed to them. The nails to pass through both, and their points are to be clenched. The Posts are to be of oak, the top sawn to the requisite dimensions and form, and a small cap fixed upon each. The bottoms of the post must be charred. The gate irons shall be of the form and dimensions shown on the drawings. The Gates must be firmly fixed in the line of the quicksets, and the wood railing neatly joined to the gate posts. The gate posts must be painted in two coats of white or stone-colour paint.

EXCAVATIONS AND EMBANKMENTS OF SLOPED OCCUPATION ROADS.

These Excavations and Embankments are to be made in the same manner as those upon the line of Railway, and slopes, as may be directed by the Engineer. The contents of the excavations shall be conveyed to the nearest embankment upon the line of Railway, or to the nearest spoil bank. The embankments are to be formed with the surplus material in the excavations upon the line of Railway, should such exist; but if not, they must be made with material obtained from one or more of the excavations upon the line of Railway, as may be fixed by the Engineer, by altering the Slopes, so as to afford a sufficient supply; and the Contractor shall be paid for the same at the rate specified in the Schedule of Prices. But whenever there is a surplus of material, the Contractor shall employ the same in forming the Approaches to occupation bridges, or sloped roads, should such be required; and the cost of so employing it shall be considered a part of his contract, to which the stipulations and prices of extra works do not apply.

METALLING OF APPROACHES TO OCCUPATION BRIDGES.

To be done in the same manner described in the Specification of approaches to bridges.

PAVED CROSSINGS.

All the Roads crossing the Railway without bridges, are to be paved in the manner shown in the drawing, with good 6 or 7 inch Aberdeen granite, or other granite equally good. The paving must be laid on a bed of fine clean gravel, of 12 inches in thickness, in a solid and substantial manner. The paving stones must be cubes, as nearly as possible. Each rail must be protected by two iron Bars, as shown in the drawing; they will be considered as part of the rails, and will be provided by the Company.

OCCUPATION BRIDGES.

The general form of Bridges which will be used as Occupation bridges is shown on the drawings. For particulars of Materials and Workmanship, see General Stipulations hereinbefore given.

CULVERTS.

Vide Plate 21.

The form and dimensions of the Culverts are shown on the drawing, the sizes being selected to suit the particular situation. For particulars of Materials and Workmanship, see General Stipulations hereinbefore given.

LAYING AND BALLASTING PERMANENT SIDINGS.

The Sidings are to be laid in such positions, and of such lengths, as may be directed by the Engineer. They must be laid in the manner and form shown on the drawing. The Contractor will be required to take up any part of the rails already laid down which may be found necessary, to cut them into their proper lengths for the reception of the other iron work, to relax them, and to fix all the necessary crossing plates, check rails, moveable points, or sliding rails, with the requisite machinery for removing them. The whole must be made equally firm and substantial as the other parts of the permanent way. The Specification of the permanent Ballasting, already described, must be considered applicable in all respects to the construction and ballasting the sidings.

TOOL RECESS.

Tool Recesses, similar to that represented in the drawing, shall be built in such situations and intervals on the side of the railway as may be directed by the Engineer. They shall be constructed of brickwork, with stone coping. For particulars of Materials and Workmanship, see General Stipulations attached to bridges.

DISPOSAL OF MATERIAL.

Throughout the whole of this Contract, the material from the excavations is to form the next adjoining embankment, as well as the approaches to the bridges, and crossings, of every description; and whenever, or wherever, any excavations shall not be sufficient in quantity to complete the next adjoining embankment, and approaches to bridges, and sloped roads, the quantity so deficient must be brought from the nearest excavation which shall have a redundancy. After excavation, No. 31, shall have been carried into embankment, No. 23, the deficiency of

material to complete this embankment must be obtained from the redundancy in the other parts of the contract, including the material out of Northchurch Tunnel. If there should be a redundancy of material in the excavations, such redundancy may be laid in spoil bank if not required, to be otherwise disposed of by the Engineer. If there should be a deficiency of material in the excavations to form the embankments, the quantity required to complete them must be obtained by altering the slopes of such of the excavations as the Engineer may think proper to order, and at the cost of the Contractor.

The entire surface of the Spoil Banks must be finished off with a regular, even, horizontal plane, excepting the outer edges, or boundaries thereof, which must be finished off with slopes of not less than 6 to 1. The area to be occupied by the spoil banks is to be stripped of all turf, or soil, previously to depositing the spoil thereon; all of which turf, or soil, shall be afterwards equally distributed over the surface of the spoil banks. The whole surface of the Spoil Banks, including their slopes, must then be sown with grass and clover Seeds, as hereinbefore described for the slopes of the excavations. All damage done to the lands by the occupation of, and during the execution of the above works included in this contract, and in the formation of spoil banks, to be defrayed by the Contractor. The Company binding themselves only to exercise the power of their Act of Parliament, in aiding the Contractor to purchase or to settle compensation for such Lands as he may select for the formation of spoil banks, or for other lands injured, or occupied, temporary or permanently, by any works or erections, or for any side Cuttings which the said Contractor may employ, or require, beyond the width purchased by the Company, and described in the field plan.

TIME OF COMPLETION.

The whole of the Works in this Contract are to be completed on or before the 1st day of May, 1837, and the Contractor will be bound to keep in good order and uphold the whole of the works, for the space of one year after the works shall have been completed.

RATE OF PROGRESS.

Embankments Nos. 24, 25, 26, and 27, shall all be made on or before the 1st day of August, 1836, and at the same period, 100,000 cubic yards of the embankment, No. 23, must be formed.

150 yards in length of the Northchurch tunnel to be completed in the same period.

In the same period, the foundations of the Bridge over the Grand Junction Canal, the site of which is represented between the fifteenth and twentieth chain on the section, must be laid, and the walls built up to the level of the springing of the arch.

On or before the 1st day of March, 1837, the whole of the excavations and embankments, and the whole of the Northchurch Tunnel, to be completed.

It is understood, that only the neat Measurement of the masonry, brickwork, or timber, will be allowed, notwithstanding any custom to the contrary.

CONTRACT No. 1, F.

SPECIFICATION of the various Works to be executed in making and completing a portion of the said Railway, extending from, at or near the boundary between the Counties of Buckingham and Northampton, near Hartwell, to a part near the Grand Junction Canal, in the parish of Blisworth.

EXTENT OF CONTRACT, AND GENERAL STIPULATIONS.

This Contract commences at or near the boundary between the Counties of Buckingham and Northampton, at a point marked with the letter A, in a field in the Parish of Hartwell, belonging to the Trustees of Stony Stratford Poor, numbered 2 on the Field Plan, marked Drawing No. 2, and on the section, marked Drawing No. 2, hereto respectively annexed, and thirty-nine statute chains, or thereabouts, on the South East side of the road leading from Bŏzenham Mill to Hartwell, and terminates at a point marked with the letter Z, in a field in the Parish of Blisworth, in the County of Northampton, belonging to his Grace the Duke of Grafton numbered 35 on the said general plan and section, the point about twenty-seven statute chains on the North West side of the road leading from Towcester to Cotton End, being a distance of five miles or thereabouts.

It comprehends the following Works.

The making of Temporary fences necessary during the progress of the other works.

The formation of the whole of the Excavations and Embankments represented on the section.

The making of the Permanent fencing.

The erection of Bridges *under* the Railway, viz.

At the crossing of the road leading from Bozenham Mill at Hartwell.

At the crossing of the road leading from Stoke Bruern to Hartwell.

At the crossing of the road leading from Ashton to Hartwell.

At the crossing of the turnpike road leading from Towcester to Cotton End, Vide Plate 25.

The erection of Bridges *over* the Railway, viz.—

At the crossing of the road leading from Ashton to Roade.

At the crossing of the turnpike Road leading from Hardingstone to Old Stratford.

At the crossing of the road leading from Roade Hyde to Roade.

At the crossing of the road leading from Roade to Plane Woods.

At the crossing of the road No. 2 leading from Roade to Plane Woods. Vide Plate 23.

At the crossing of the road leading from Blisworth to Roade.

At the crossing of the road leading from Blisworth to Courteen-hall. Vide Plate 24.

The formation of Roads over or under the above bridges, and Metalling the same; and also for diversions.

The making of the following Culverts, viz.—

Two double, 6 feet in diameter.

One single, 6 feet ditto.

Three ditto, 4 feet ditto.

Three ditto, 2 feet ditto.

The formation of the side Drains in the excavations on each side of the Railway.

The laying, ballasting, and draining of the Permanent way, including the providing of all Timber, bricks, lime, stone, or other materials necessary for the completion of the works.

The iron Rails, chairs, keys, pins, trenails, blocks, and sleepers for the purpose, being provided by the Company, under conditions hereinafter described.

And all other Works mentioned or described in the accompanying drawings or plans; together with the following

EXTRA WORKS.

The erection of Gates.

The excavation and embanking of Approaches to occupation bridges.

The Metalling of occupation roads.

The Paving of occupation roads crossing the Railway on a level.

The building of Occupation Bridges and Culverts.

Laying and ballasting permanent Sidings, and the formation of Tool recesses are considered as Extra works, and will be paid for as such, according to the schedule prices for extra works set out in the tender.

The preceding enumerated Works, and the mode of execution, are described at length in the Specification of each particular work, and their forms and dimensions are described in the accompanying drawings, which are referred to in each specification; but should any discrepancies exist between the measurement by the scale attached to the drawings and the written dimensions, or between the drawings and the specification, or any ambiguity in them, the same is to be referred to the Engineer, whose decision shall be conclusive. Anything contained either in the drawings or specifications shall be considered as being contained in both. The written dimensions are those by which it is intended the Contractor shall make his estimate. The clause relative to the "Fencing and Ditching, and the temporary and permanent Fencing," is similar to that specified in Contract 5 B, hereinbefore given, (vide page 47.)

EXCAVATIONS AND EMBANKMENTS.

The part coloured Red on the Field Plan, Drawing No. 2, shows the direction of the Railway, and the area of the land which will be purchased by the Railway Company, and upon which the Contractor shall have full permission to erect any temporary houses, offices, &c., necessary during the execution of the works, or any machinery for excavating or embanking, provided that such proposed erection shall not be especially prohibited by the Act of Parliament for making the Railway.

The Blue line on the Section Drawing No. 1 describes the top of the embankments and the bottoms of the excavations previous to the laying and ballasting of the permanent way.

The uncoloured space on the Section below the blue line represents the embankments, and the space between the blue line and the surface shows the excavations.

The Black undulating line describes the present natural surface of the ground along the centre of the line of the Railway, showing the respective heights of the embankments and depths of the excavations, from which data their contents have been calculated, on the supposition "that the area of any cross section in sidelong ground does not differ from the area of a similar section in level ground."

The levels and other admeasurements from which the section is made are believed to be accurate, but the Contractor must verify the results, as he will be held liable for the consequences of any error.

Cross Sections of a Cutting and Embankments, with drains, fences, &c., are shown in Drawing No. 19.

EMBANKMENTS.

The whole of the Embankments in this Contract shall have Slopes of 2 to 1, that is to say, when the Base of the slope is 2 feet, its perpendicular height shall be 1 foot only, and they shall be 33 feet wide at the level of the blue line on the Section, neither more nor less; which width shall extend equally on either side of the outside rails after they shall have been laid and completed, as hereinafter described. Each of the Embankments shall be uniformly carried forward as nearly at the finished heights and widths as the due allowance for the shrinking of the materials will admit of, and this allowance shall not exceed or fall short of the quantity deemed necessary by the Engineer. In all cases this must be carefully and strictly attended to, in order to avoid the necessity of making any subsequent addition either to the heights or widths of the embankments, to bring them to their proper level and dimensions.

The surface of the Embankments shall be kept in such form, or be intersected by such drains, as will always prevent the formation of pools of water upon them, and insure the embankments being kept as dry as possible.

Whenever the material teemed over the end of the embankments shall not form the proper Slope, it shall be carefully trimmed to its required form; and this operation must proceed at the same time with the end of the embankment, so as to obviate the necessity of any further addition of material to the sides of the embankment.

As the Embankments advance and become consolidated, the Slopes shall be carefully trimmed into planes having the proper slope, and be neatly faced or ramped with an uniform covering of turf of not less than 8 inches in thickness, and laid with the greensward outwards. The Turf must be taken from the ground to be occupied by the base of the embankments; and where the land is arable, the slopes of the embankments shall be covered with the Soil, which must be uniformly laid on, of the thickness of 6 inches, and sown with rye-grass and clover-seeds, as soon as the proper season will admit of its being done; not less than one pound and a half of clover-seed and one pound and a half of rye-grass seed to be sown on each acre.

When the materials brought to the embankments consist of large lumps, they shall be broken into pieces of not less than 6 inches in diameter, unless they consist of rock.

EXCAVATIONS.

The Excavations throughout the Contract shall, when turfed or soiled, be 33 feet wide at the level of the blue line on the Section, neither more nor less, and shall extend to an equal distance on each side of the outside rails, except in certain parts of the excavation No. 5, where Retaining Walls are inserted, in which case the widths are variable; and the Contractor is referred to the drawing and specification of that part of the line.

The Excavations in this Contract are five in number, and are designated in the Section as Nos. 1, 2, 3, 4, and 5.

Trial Shafts have been put down in all the excavations, to ascertain the nature of the materials to be excavated; and the nature, thickness, and relative positions of the various beds of Clay, marl, shale, limestone, &c., are shown in the Section, which it is believed correctly represents the extent and quality of the materials to be cut through; but it remains with the Contractor to verify the correctness of the section, as he will be held liable to the consequences of any alteration in the continuity of the strata between the shafts.

The Shafts have been left open for examination; the materials obtained in sinking them may be seen at the top of each shaft, and samples of the various strata sunk through may be seen on application at the Railway-office at Weedon.

As soon as any part of the Slopes, not having less base than $1\frac{1}{2}$ foot to every foot in height, are dressed to the proper inclination, they shall be covered with Turf taken from the land to be occupied by the excavations in the same manner as before directed in the embankments; and where turf cannot be obtained, the slopes must be covered with Soil and sown with rye-grass and clover-seed, as before directed in the specification of the embankments.

In the formation of the excavations and embankments in this Contract, the Contractor shall not remove the turf or soil from the ground for a greater distance than half a statute chain in advance of the face of the excavation or embankment, and that which has been cut must be removed back to a point where the slope is ready for receiving it, and laid down as directed, with as little delay as possible.

Whenever and wherever springs, soaks or streams of water, may appear and issue from the face of the slopes, the Contractor shall be bound to make and maintain during the progress and until the completion of the works, such Drains or water-courses as shall completely and effectually prevent such springs, soaks or streams of water, from injuring the slopes, and shall convey the whole of such

water into proper Drains, so that none shall be permitted to lodge in the excavation: and where beds of Sand, gravel, or other loose mould occur, the face of the slope must be protected from the injurious effects of such springs or streams of water by any other means than may be deemed advisable or necessary by the Engineer.

At the bottom of each slope, a Drain of an uniform depth below the rails, as shown in the drawings, shall be made, and these drains must be continued on both sides under all the bridges which cross the Railway. A Drain shall also be made at the top of each slope, so as to exclude from the excavations any water draining off or flowing from the lands adjoining, and all covered or open drains which may be intersected by the excavations, must be made to discharge their water into the ditch at the outside of the top of the slope, for which purpose the said ditch shall be made as deep at least as the bottom of the intersecting drain, and the space between the outside drain and the slope shall be well puddled at the point of intersection.

The Contractor shall also open or make any new Drain which the Engineer may deem necessary for the exclusion of any water from the Railway excavation.

In the formation of the Excavation and Embankments, the Contractor must provide, at his own expense, all the necessary Rails, chairs, keys, pins, blocks and sleepers, as well as Waggons, barrows, planks, or other machinery, materials, or utensils, which stipulation is, however, modified to a certain extent by the following conditions:—

It is not intended to deliver to the Contractor any of the Permanent Rails, chairs, keys, pins, blocks or sleepers, until at least one continuous mile of roadway, together with 300 yards in continuation at each extremity of such mile, shall have been completed; also certified by the Engineer as being ready for the reception of the permanent ballasting, as in the Contract hereinbefore mentioned, on which certificate a sufficient number of Rails, chairs, keys, pins, blocks and sleepers shall be delivered to the Contractor by the Company, and he shall be permitted to use them in such manner only as is hereinafter described in the specification of the ballasting and laying of the permanent way, provided, however, that such permanent rails shall in no case whatever be laid down and employed within 300 yards of the face of any excavation, or the end of any embankment then in progress.

From the Shafts that have been sunk in the cutting No. 5, it is expected that a considerable quantity of Stone will be found sufficiently hard for the purpose of Blocks such as described in the drawings and specification of the ballasting and laying the permanent road.

In all and every case, either in the above-named excavations, or any other within the limits of this Contract where Rock exists, (which, in the opinion of the

Engineer is proper for making blocks,) the Contractor shall proceed in such manner as may be best calculated for obtaining blocks of the size and quality specified under the head of ballasting and laying already alluded to, and shall obey the directions of the Engineer in working such rock. For each block so procured and delivered at the situation within this contract where it will be used, the Contractor shall be paid by the Railway Company one shilling over and above the amount of his tender; and should the Contractor in any case where stones exist suitable for blocks, neglect to work it in the manner best calculated for obtaining them both sound and in the greatest quantity, he shall be liable to a deduction from the amount of his tender, equal to the estimated value of the blocks which might have been obtained. The estimate of value shall be made by the Engineer.

Whenever Material occurs in any of the Excavations of a quality suitable for making Bricks, the Contractor shall be at liberty to make use of such material for that purpose; but if in so doing he shall cause any deficiency in the material for the formation of the embankment, he shall make up such deficiency in the material by a Side Cutting, at his own expense, in such of the excavations as the Engineer may point out, and if such side cutting require an additional quantity of ground, the Contractor shall indemnify the Company for the purchase of the same.

The excavation No. 1 consists of Clay and Shale, and the sides are to be formed at a Slope having a base of 2 feet for 1 foot in perpendicular height.

The excavation of No. 2 consists of rubbly Sandstone, Limestone, and Shale, (as shown in Section No. 1,) and the sides must be formed at a Slope having a base of 1 foot and a half for each foot in perpendicular height.

The excavation of No. 3 is nearly similar as regards material to No. 2, and the sides must have a like Slope of 1 foot and a half to each foot in perpendicular height.

The excavation No. 4, is principally Soil and Clay, and must have the same Slope in the sides as Nos. 1, 2, and 3.

In the excavation No. 5, the strata are of various kinds, consisting principally of a bed of Limestone extending nearly throughout the excavation, which bed of limestone is overlaid by beds of Clay and Marle in the deepest parts of the cutting, and underlaid by a thick bed of Shale throughout its whole length. The sides of the excavations must have Slopes of various inclinations, (hereinafter particularly described,) according to the nature of the materials to be cut through, from the end of the cutting A to the point B; the sides shall be taken out to an uniform Slope of 2 feet base to 1 foot in perpendicular height.

Throughout the whole of the remaining part of the excavation, all Soil, Clay, Sand, Marle, or other materials above the aforesaid limestone rock, shall be taken out at a Slope of 2 feet base to 1 foot in perpendicular height, between the foot of which slopes and the top of the cutting in the rock a Bench of 9 feet in width shall in all cases be left. The Slopes of the cutting in the limestone Rock to have 3 inches base to 1 foot in perpendicular height.

Whenever the Shale or other soft strata lying under the limestone is found to rise above the level of the bottom of the cutting, a portion of such shale or soft strata shall be excavated from under the limestone on each side of the cutting, and replaced by Walls, buttresses, arches, and inverts, as hereinafter described.

Whenever the depth or thickness of such Shale or soft strata falls short of 14 feet, the side walls shall be of the dimensions shown in Drawings Nos. 3 and 4, and described in the specifications relative thereto.

To prevent any injury to the Slopes by the springs of water issuing from the rock and other strata in this excavation, the strictest attention will be required on the part of the Contractor, and the modes of drainage adapted to the varying thickness of the shale and other strata are particularly described in the Drawings Nos. 3 and 4, and the specifications relative thereto.

Drawing, No. 4.

Vide Plate 22. Undersetting of the Rock in the Blisworth Cutting.

Fig. 1.—Represents a cross section of such excavation where shale rises to the height of 22 feet above the bottom of the cutting.

AB.	Fig. 1.	Is a cross section of a buttress.
CD.		Is a longitudinal section of one half of an invert.
EF.		Is a cross section of the recess wall.
GH.		Is a cross section of a drain in the centre of the cutting.
IK.		Represents the method of carrying off the water from behind the wall.
LM.		Section of pitching between buttresses.

Fig. 2.—Is a plan of the retaining walls and buttresses.

AB.	Plan of buttress.
CD.	Plan of invert.
EF.	Plan of recess wall.
GH.	Plan of central drain.

A. Fig. 2.—Side drains, communicating with central drain by means of cross drains bb.

IK. Sunk drains in face of wall, communicating with side drains AA, by sunk drains CC.

LM. Plan of pitching between buttresses.

The Inverts to be of an invariable width of 27 feet, and to have a rise of 3 feet 3 inches; the radius being 29 feet 8 inches; the junction of which inverts with the face of the buttresses to be always at the level of the surface of the rails.

The face of the Buttresses in the cross section to be described by a radius of 106 feet; the radius to be square with the face of the rock, at its junction with the top of the buttresses; therefore, rising 3 inches vertical to 1 foot horizontal, corresponding to the slope of the rock.

The back of the Buttresses to batter outwards, from the centre of the cutting, at the rate of $\frac{3}{4}$ of an inch horizontal for 1 foot in height, as shown in the section; and the side of the buttresses to batter, at the rate of 1 in 20, on each side, as shown in the plan and elevation.

The Recess Walls to have the same batter at the back, corresponding with the buttresses, and the face of such walls to have a straight batter, of 2 inches horizontal to 1 foot vertical. These walls shall have three courses of 1 foot each in depth; each course to step 6 inches. The bottom of the walls to be level with the bottoms of the inverts and buttresses.

The central Drain to be made according to the dimensions in plan. Where it crosses the inverts, they will form its bottom; and between the inverts, the bottom to be laid to an uniform inclination.

At a depth, never falling short of 1 foot below any wet stratum that may occur, two courses of the recess wall and buttresses to be projected beyond the back of the wall; the lower course to project beyond the upper, so as to receive a stone, to rise 1 foot above the upper course, forming a Drain 12 inches deep and 6 inches wide; to be surrounded at the bottom and back with a casing of sound Puddle, and filled in at the top with Rubble stone, to allow the top water to have access to the drain, as shown in the Drawings at IK. This drain to have a regular fall from the centre of each buttress, as shown by the dotted lines Nos. 1 and 2, in elevation Drawing No. 4.

The water, when thus collected, shall be carried through the recess wall, and down the sunk channel in its face, as shown in section and elevation of Drawing No. 4.

The pitching between the buttresses to extend from the foot of recess walls to the side drains AA.

The Inverts being preserved of a constant width, at the level of the surface of the rails, and the face of the buttresses being an uniform curve, proceeding from the slope of the rock, at its junction with the top of the buttress, the width between the tops of any two Buttresses on section "will depend upon the depth of the shale above the bottom of the cutting." The width of the said Buttresses viewed in elevation being invariably 4 feet at top, the same circumstance will affect the width of their junction with the inverts: the same circumstance will also affect the thickness of the recess wall and buttresses. Thus, in Fig. 3, Drawing No. 4, where the shale is 22 feet deep, the width between the top of the buttresses is 41 feet 6 inches; while in Figs. 4, 6, and 7, Drawing No. 4, where the depth of the shale is 14 feet, the width is 34 feet 2 inches. This will also in like manner determine the width of Excavation at the bottom of the rock, which being flush with the face of the buttresses at their top, overhangs the recess wall 1 foot 6 inches.

When the depth of the Shale, from the bottom of the rock to the bottom of the cutting, shall be less than 14 feet, then the Inverts between the buttresses shall be discontinued, and in lieu of the inverts, the buttresses shall have 4 courses of Footings, when the depth of Shale above the bottom of the cuttings exceed 10 feet; and 3 courses for all lesser depths. Further, when, as aforesaid, the Shale, or clay, or other soft material, rises to the height of 10 feet above the bottom of the cutting, then the level of the bottom Footings of the buttresses shall be 3 feet 3 inches below the said cutting, which depth shall decrease proportionally as the above height diminishes, until the rock meets the level of the bottom of the said cutting.

Where there are no Inverts, (which is invariably the case where the depth is less than 14 feet,) the distance between the tops of the buttresses, and consequently the width of the excavation between the tops of the buttresses, shall be uniformly 34 feet 2 inches.

The face of the Buttresses, and recess walls, being determined in this case by the same rules as where the inverts exist, and the width at the top buttresses being constant, the width of the cross section at the level of the rails will depend upon the depth of the shale, as will be seen by referring to Figs. from 4 to 13 inclusive, Drawing No. 3; where it will be seen that by this means the Cross Section at the top of the undersetting gradually approximates in width and form to the ordinary shape of the cutting in rock.

The North-west end (C) of the Retaining Wall terminates by a buttress, and at 38 feet North-west of the buttress (extending to B) the excavation, as before stated, will have an uniform slope of 2 feet base to 1 foot in height.

Between the points C and B, the form of the Excavations will be determined by straight lines, drawn parallel to the surface of the Railway from corresponding points in the face of the cross section at C and B. Throughout this extent (from C to B) the Shale beneath the rock will have a facing of masonry, (commencing at C and terminating at B,) as shown in Figs. 1, 2, and 3, Drawing No. 3.

The back of this Retaining Wall to be determined in a similar manner to the front, by straight lines being drawn from corresponding points at the back of the buttress at C, to the same at the back of the lining at B, thus lessening regularly in thickness from C to B.

To render this description more easily understood, a Model of the North-west, and of the Cutting, accompanies the plans.

MATERIALS AND WORKMANSHIP FOR WALLING.

The whole of the Walls and Buttresses to be of masonry; the stones to be procured from the excavations. The courses to run as thick as the material obtained from the excavation will afford when properly quarried. The facing stones to be at least 18 inches; the beds to be square with the face of the buttress, or wall.

The stones to be hammer dressed, and brought to a rough bed, but perfectly true; special care being taken to prevent too full a bearing in the centre of them.

Their faces will not be required to be smooth dressed, but rough nobbled, similar to pitching, with rustic joints. If it should so happen, that after the quantity of sufficiently large stones shall have been procured to form the faces of the walls and buttresses, the excavation will not afford any of a similar description for the backing, then the said backing may be formed of Rubble, set in mortar, as hereinafter described; the stones composing which to be brought to a bed, top and bottom, laid in courses. It being understood, that the Engineer or Engineers for the time being shall have the sole option of determining the necessity of adopting and the manner of performing the Rubble work. The bottom of the Rock to be taken out, to receive the walls and buttresses, as shown in the plans and sections; and stones, corresponding as near as possible with those shown in the said section, to constitute the top of the said walls and buttresses. The stones to be accurately fitted to rock, and soundly fixed, so that for the whole depth of the said walls and buttresses, the rock shall rest upon them.

The object of this arrangement being to secure a sound support to the rock, and to effect by the dove-tailed Stones a connexion with the rock, to prevent the top of the wall being pushed out.

The Spandrels of the inverts and base of the buttresses to be filled with masonry in courses, and the angle made good, as shown in the Fig. 1, Drawing No. 4.

The bottom course in all cases to be composed of stone as large as can be obtained, and the bottom be worked true.

The bottom of the Buttresses and walls, when there are no inverts, to be laid on a level bottom, the courses to be brought gradually to radiate with the wall at the top of the footings, by the varying thickness of the courses, as shown in the Figs. 5 and 8, Drawing No. 3.

The courses of the Masonry in the walls between the points C and B, at the North West end of the walling, to correspond with those of the buttress at C, and to have the same inclination or rake. The increasing batter to be obtained by enlarging the width of the benches between the upper and lower courses in the face of the wall. The working, setting, and mortar for this walling will be similar to that specified for the buttresses and recess walls.

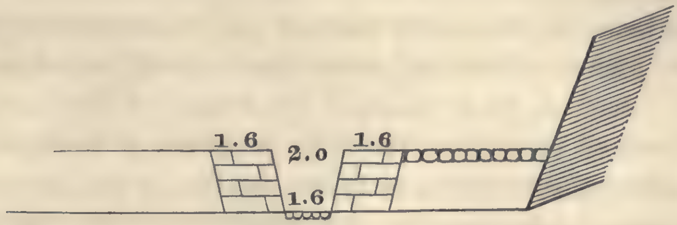
The Invert to consist of stones laid in regular courses, and each stone 2 feet in depth; the stones to be brought to a smooth bed, and radiated to the centre of the courses.

The Skew back at the end of the invert to be formed so as to suit the radiating course of the invert and the buttress, and to be not less than 9 inches deep on the face. The sides of the centre Drains to consist of masonry according to dimensions on plan, the interior face being fair and regular. The top to consist of an arch of brickwork set in mortar, or covered with stones, if they can be procured large enough to stretch across the drain, and to bed 4 inches on each side between the inverts; the bottom of the drain to be pitched with stones or brick brought to a fair face.

The Side and cross Drains to be formed either of brick or stone, neatly faced at the sides and bottom, and set in concrete mortar of the description hereinafter described.

The centre Drain will not be required between the points H and I, at the South East end of the cutting, and instead the side drains A A will be made 2 feet wide at top and 1 foot 6 inches at bottom, and deepened so as to be level with the bottom of the excavations; their bottom to be pitched and finished similar to the centre drains, and the drains for the cutting between D and H to

be diverted by similar drains into the above. The side walls of the above to be of stone, or brickwork set in mortar, and to be 1 foot 6 inches thick: thus—



The Mortar to be used in *the beds and faces of buttresses, walls, sides of drains and invert arch*, to consist of one part Lime to three parts of clean river or other unexceptionable Sand. The sand to pass through $\frac{1}{4}$ inch skreens; the lime to be fresh, and well intermixed with the sand through beating.

The Mortar for running into *the upright joints of the courses, and for filling in the work sound*, to consist of one part Lime to four parts of small unskreened Gravel, to be well mixed and beat to a tough consistency and liquefied in tubs or other vessels, to be properly adapted to run into and fill up all vacuities. The mortar to be used as hot as is consistent with the safety of the work, and the sand and gravel to be perfectly free from any loamy or other particles of a muddy nature.

The Limestone rock found in the excavation may be used for the mortar specified to be used in the retaining walls in this Contract.

The Pitching between the buttresses to consist of 4 inch pitchers, procured from the excavation, and neatly squared; their base to be four-fifths their top face, and to be laid to an uniform surface, falling from the recess walls to the longitudinal drains, and filled in with grout made of mortar similar to the face mortar previously described, only with one part lime to five parts sand.

All spaces behind the walls and buttresses, and in front of the footings beneath the ordinary bottom of the cutting, shall be filled with Clay or other suitable material thoroughly punned in; and if through mistake, or otherwise, any excavation for walls, buttresses, or inverts, shall be made below the proper level, the space shall be filled up to the proper level with Masonry or Concrete, at the option of the Engineer.

The Puddle behind the wall, for preventing the water from the wet clay intermingling with the dry strata beneath, to be at least 18 inches thick, and to consist of clay proper for the purpose, to be thoroughly worked in with the original strata of dry clay or shale.

The broken stones above not to be less than what will pass through a $1\frac{1}{2}$ inch ring, and to be laid indiscriminately, without any gravel, sand, or other loose

material being intermixed in their interstices. This provision to be made whenever any wet strata shall be encountered.

Throughout that portion of the Excavation where the retaining walls are required to be built, the face of the cuttings shall in no case be advanced beyond the completed portion of the wall more than a length equal to the distance between two buttresses, so as to avoid the weight of the Rock breaking or injuring the natural solidity of the Clay or Shale; and should it be found necessary in effecting this object, to follow the face of the excavation with the retaining wall at a less distance than that already stated, the Contractor shall do so, or otherwise support the exposed portion of the Shale by efficient Shoring, at his own proper cost and charge.

It will be understood, that the whole object of these precautions is to prevent the natural beds of the Shale being disturbed by the pressure of the Rock or dripping of water, previous to the retaining walls being completed, as already specified.

All moulds, templets and materials that may be requisite for the due execution of the above works, are to be furnished at the charge of the Contractor.

If the Engineer or Engineers for the time being, during the execution of the works, shall see fit to extend or diminish the length of the Walling, number of buttresses and inverts, or to alter the quantity of any excavation or other work scheduled, then a proportional deduction or addition shall be made according to the Schedule of Prices, or if any strata or fissure of Clay shall occur in the limestone Rock itself, then the clay or shale in such fissures shall be faced with masonry, according to the direction of the Engineer or Engineers for the time being, and paid for according to the Schedule of Prices.

Throughout the whole of this Cutting, the slopes of the Clay and Shale above the rock, and the Fencing and ditching, will be executed as for the rest of this Contract.

The face of the Rock will not be required to be taken out to a smooth slope, but no projections or indentions on its face shall exceed 3 inches beyond the blue line of slope; and if any loose lump or mass of rock shall occur in the slope, so as to be deemed insecure by the Engineer, then the said mass or lump of rock shall be removed at the charge of the Contractor.

EXTENT OF WALLING AND EXCAVATION.

The undersetting of the Rock in excavation No. 5 (the Blisworth Cutting, vide Plate 22) extends from the point marked D to the point marked B in the

Section No. 1, a distance of 660 yards, and also between the points marked H and I, a distance of 440 yards. Of the length between B and D, the space B to E, extending 396 yards, will require inverts in addition to the walls and buttresses. The remaining space from E to D, 264 yards in length, and also the part included between H and I, extending 440 yards, as aforesaid, will only have the walls and buttresses, the inverts being omitted.

However, as the shafts merely indicate at different points the depth and thickness of the various strata, such Strata in the intermediate distances may not be shown precisely correct upon the section; and any increase or diminution over or under the quantity of work calculated from the section, will be added to or deducted from the amount of this contract, according to Schedule of Prices accompanying the tender.

The central Drain will be carried beyond the point C to the end (A) of cutting No. 5, at the same level below the bottom of the cutting as where the walling exists, and at A to be diverted into one of the side drains at the foot of the embankment.

DISPOSAL OF MATERIAL OF EXCAVATION.

The material yielded by Cuttings, marked on the Sections Nos. 1, 2, 3, and 4, to be deposited in embankments, marked Nos. 1, 2, 3, and 4. The remainder of the material requisite for the completion of the said embankments, 1, 2, 3, and 4, to be obtained from the cutting No. 5.

The Embankments No. 5 to be formed entirely from the remainder of the material yielded by cutting No. 5.

In this Contract the aggregate contents of the Cuttings being rather greater than the Embankments, the Contractor, after having supplied the quantity requisite to form the approaches to raised occupation roads, shall be at liberty to employ any remaining redundancy for ballasting the surface of the road, provided such redundancy consist of Rock or other material suitable for the purpose, and in conformity with that part of this specification wherein the Ballasting and laying of the rail is particularly described.

Throughout this Contract the Cuttings consist of variable proportions of Rock, Shale, and Marle; the Contractor will therefore be required, throughout the progress of the different excavations, to make such arrangements as will insure the Rock, Shale, and Marle being yielded from time to time by each cutting, in such proportions, and disposed of at each embankment in such manner, as will effectually secure the embankments being composed of shale and marle in the centre, with a covering of rock on the tops and slopes.

It is not intended, however, that the Rock shall in any way be set by hand, but merely trimmed into an uniform slope, and covered with Soil and sown with Seeds, as already stipulated under the head of embankments.

GENERAL STIPULATIONS,

Which are to apply to the whole of the Bridges, Culverts, and other Works wherein the workmanship or materials described may be used.

BRICKWORK.

The Brick made use of shall be hard, sound, square, well burnt, and of good colour. No broken bricks will be allowed, and no joint of mortar shall exceed one-quarter of an inch in thickness; no difference of workmanship will be allowed in inside and outside work, and the whole of the joints shall be flushed up solid with mortar, and the outside joints neatly drawn. The bond may be either English or Flemish, as the Engineer may direct.

MORTAR.

The Mortar shall consist of fresh burnt Lime, equal in quality to that from Dudley, and sharp Sand, mixed in the proportion of three measures of sand to one of lime; they must be mixed in a dry state, and well tempered by passing through a pug-mill, with a proper quantity of water. Should the Limestone obtained from the excavations in this Contract, or in any adjoining quarries, be deemed suitable for building purposes by the Engineer, the Contractor shall be at liberty to employ it.

ROMAN CEMENT.

The Roman Cement shall be of the best quality, recently made, and shall be mixed with an equal proportion of sand. None shall be made use of which has set or become dead.

STONE WORK.

Throughout this Contract, it is intended that all Stone required for bridges, walls, drains, or other works of the like description, shall be obtained from the excavation. Should, however, the stone found in the excavation be deemed insuf-

ficient, either in soundness or other quality, for the above purposes, the Contractor shall substitute brickwork or other stone work equal in quality to the best Derbyshire Bramley Fall, in such places as the Engineer may direct, allowance being made for the same according to the prices stated in the Schedule.

VOUSSOIRES.

The stones of Voussoires of Bridges must be neatly hammer dressed (except when directed otherwise); the joints chamfered; the beds dressed true and smooth; each Voussoire to consist of one stone not less than the full thickness of the arch, and to break joint into the body of the arch not less than as shown in the drawings.

STRING COURSES AND FACIAS.

String courses and facias must be fairtooled throughout, except at the back. No stone to be less than 2 feet 6 inches in length. The depths and widths, together with the forms, are fully described by the drawings.

PARAPETS.

The Parapet, when of stone, must not be in more than three courses in depth; the stone must be neatly hammer dressed, and the beds and cross joints made perfectly smooth. The average of the stones must be 2 feet in length.

COPING.

Coping, when upon bridges which pass over the Railway, must be neatly fairtooled; the stones dowelled, and to be leaded together. No stone shall be less than 2 feet in length. The cross joints and beds shall be made perfectly true. The form and dimensions of the Coping are fully explained by the drawings.

ARCHES.

When Arches are of *Stone*, to consist of stones not less than 24 inches on the soffit. All the surfaces must be hammer dressed perfectly true when they are in sight. The beds and joints to be chisel dressed, and accurately fitted. When the arches are of the Skew principle, especial care to be taken in working the

skew backs with planes, truly square with the spiral direction taken by the arch stones. Where counterforts are added, the arch stones must be made longer, so as to abut in the manner of an arch against them, and form a rib on the back of the arch, and continued as near to the crown as shown on the drawings.

When Arches are of *Brick*, they shall be laid either in concentric half-brick rings, or in such other manner as the Engineer may direct. In this case, the counterforts shall be bonded into the arch, as just described for stone arches. The courses of brick in the counterfort radiating, so as to correspond and bond into the arch.

IMPOSTS.

Imposts to arches shall be made of stone, of sufficient width in the beds to receive the whole thickness of the arch; and no stone shall be less than 2 feet 6 inches long; and, where required, they shall be dowelled together. In cases of Skew arches, the skew backs must be cut or worked, so as to suit the direction of the springing of the courses. The stones to be dressed in the same manner as described under the head Arches.

STONE FACING TO THE ROCK UNDER BRIDGES, &c.

The Stone shall be in courses of from 8 to 12 inches in depth, worked in regular header and stretcher. The headers to be the full thickness of the wall, and the stretchers on an average 2 feet 6 inches long. The beds must be worked true. The bed and cross joints chamfered. The middle part of the stones, on their outside, to be left rough.

COUNTERFORTS AND RIBS OVER ARCHES.

Whenever *Stone Counterforts or Ribs* are placed upon the arches, they must be of good Ashlar work, and bonded into the thickness of the arch. The beds of the stone, as well as the cross joints, must all be dressed true. When they are *of brick*, they must be built either in the radiating direction of the joints of the arch, or in horizontal courses, as the Engineer may direct, but in all cases they must be of the same description of workmanship as the outside work.

RUBBLE BACKING.

The Rubble Backing to arches shown upon the drawings, must be built of rubble stone, carefully levelled up every 12 or 14 inches, and thoroughly grouted with mortar of the kind hereinbefore described.

SPANDREL WALLS.

Spandrel walls, when *of stone*, shall be of good sound Ashlar, set in regular courses of headers and stretchers, from 8 to 12 inches in depth, but in no cases less than 8 inches. The headers shall be the whole thickness of the walls, and not less upon the point than 1 foot wide. The stretchers shall not be less than 2 feet upon the point, and one-half of the thickness of the wall.

The whole of their joints shall be neatly hammer dressed, excepting when described to be worked otherwise, and all the beds and cross joints shall be made perfectly true.

The whole to be set in mortar, as hereinbefore described.

When the walls are *of brick*, they must be of the description hereinbefore described under the head of brickwork.

WING WALLS.

Wing Walls, when of stone, shall be of the same description as that described under spandrel walls.

EXCAVATING FOUNDATIONS.

The Contractor is to excavate for the foundations of all Bridges, culverts, and other works; to keep out the water, place dams, and provide all Centering, planks, and tools of every description, necessary to the perfect execution of his work, at his own expense, and to be included in the amount of his tender. And in case of the foundations of any of the works requiring, in the opinion of the Engineer, to be carried lower than is shown upon the drawings, the Contractor is to make such Extra excavation, and to do all Extra Pumping, or other contingent works incident thereto, at his own expense.

The increase to the Masonry, or brickwork, or other matter constituting the

foundations, caused by such additional depth, will be allowed as an Extra to the Contractor, according to the rate contained in his Schedule of prices.

FILLING-IN OVER ARCHES.

The space between the wing walls, arch, backing, and side of the excavation of bridges, to within 18 inches of the surface of the roadway, shall be filled in with broken Stone, where it can be got; to be punned hard down, and if required by the Engineer, to be mixed with a certain proportion of Lime. The metalling of the roadway, occupying the remaining 18 inches, is to be done as hereinafter described under the head of "Metalling of roadway to Bridges." If, in the opinion of the Engineer, it shall be advisable to substitute brick where stone is shown in the drawings, or vice versa, it shall be found by the Contractor; the difference in expense being added or deducted, as the case may be, according to the rate given in his Schedule of prices.

All the Centering shall be constructed to the satisfaction of the Engineer, and all string courses, parapet walls, and coping shall not be put on until after the centres are struck, which in no case shall be without the permission of the Engineer. Great care must be taken that the bridge be so placed, that the outside rails, when laid in their proper line, shall be equi-distant and parallel with the faces of the abutments.

DRAINS UNDER THE BRIDGES.

Drains must be constructed under one of the bridges on each side of the Railway, 15 inches wide at the top, 12 inches wide at the bottom, to be sunk as low as the drain at the outside of the ballasting, and will consist of a brick wall 14 inches thick, 3 feet deep, and equal in length to the width of the bridge, and as much more as shall be necessary to connect with the side drain at the outside of the ballasting. There will be two courses of brick to form the bottom. The whole will be laid in mortar in the same manner as described for the bridges.

BRIDGE FOR ROAD FROM BOZENHAM MILL TO HARTWELL.

This Bridge is to be built at a point where the Railway is about 37 feet embankment, and the direction of the arch will make an angle of about 51 degrees with the line of the Railway. The arch will be semi-circular, and must be built upon the skew principle for a distance of 10 feet from each end. Its span will

be 15 feet, height from road to soffit 16 feet, length 141 feet, and thickness 1 foot $10\frac{1}{2}$ inches. The material will be brick, excepting at the faces of the arch and the imposts, which will be of stone. The Wing Walls will be of brick, finished by square pillars of brick, and the whole coped with stone as shown in the drawings. The abutments will be strengthened at the back by means of counterforts.

For description of materials and workmanship, see General Stipulations.

PARTICULAR DESCRIPTION WITH REFERENCE TO DRAWINGS, Nos. 5 and 6.

A. Abutments of 4 feet 6 inches thick carried up as high as the springing of the arch.

B. Counterforts 3 feet square carried up 2 feet above the springing of the arch.

C. Backing to the arch carried up 5 feet 4 inches above its springing.

D. The brick Arch, 1 foot $10\frac{1}{2}$ inches thick, and worked 10 feet in from each end, on the skew principle, the courses being made to tooth into the straight courses, as shown in the drawing.

E. Stone voussoires at the end of the arch. They must be each equal to four courses of bricks on the soffit, and tooth into the brickwork. Their whole length (under the arch) being alternately 1 foot 5 inches and 2 feet 6 inches, their height must be 2 feet, and they must project $1\frac{1}{2}$ inches from the face of the brickwork, being the depth of the chamfered rustic joints.

F. Stone imposts to be 9 inches deep, and not less than 2 feet long upon the bed. They must be cut to suit the direction of the skew back, and particularly in that part where the arch is worked upon the skew principle.

G. Spandrel walls of brickwork.

H. Wing walls of brickwork, built with a batter of 1 inch to 1 foot of height.

I. Stone coping to wings to be 6 inches thick, and 1 foot 6 inches upon the bed.

K. Caps of pilasters to be of the dimensions shown upon the drawings.

BRIDGE FOR ROAD FROM STOKE BRUERN TO HARTWELL.

This Bridge is situate in a part of the Railway where it is an embankment about 36 feet high, and the road will pass under at right angles to the Railway. The Arch will be of brick, 18 feet span and 16 feet high from the surface of the

road to its soffit. The coping and caps to the pilasters will be the same as that described for the bridge for road from Bozenham Mill to Hartwell, Drawings Nos. 5 and 6. The forms of the different parts will be sufficiently seen by reference to Drawing No. 7.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ASHTON TO HARTWELL.

This Road at present crosses the Railway where the latter is in embankment of 7 feet 6 inches, but it will be diverted, as shown upon the Field Plan No. 2 and Drawing No. 20, so as to allow height for the road to pass under. The Arch will be of brick, of 15 feet span and 16 feet from the ground to soffit; thickness of the arch 1 foot 6 inches. The Wing Walls will be built at right angles to the Railway, and will terminate against pilasters in front of the arch. The stone coping and caps will be of the dimensions shown on the drawing, and worked as described in general stipulations hereto attached. The form and dimensions of the different parts will be seen in the drawing.

For descriptions of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD AT ONE MILE TWENTY-TWO CHAINS ON SECTION.

The Railway at the crossing of this Road will be in about 33 feet 6 inches cutting, and the Bridge will cross at right angles to the Railway. The Arch will be a segment of stone of 32 feet 6 inches span, 18 inches thick, and 10 feet 3 inches rise, 23 feet 8 inches from the rail to the soffit of the arch, and 15 feet in the clear between parapets. The rock forming the abutments at A must be faced with good Ashlar to support the imposts and protect the rock from weathering. The facing of the rock abutment will return round its sides 3 feet wider on each side than the outside of the bridge, until it intersects the slopes of the cutting. The dimensions and forms of the various parts of the bridge will be seen upon the drawing.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ASHTON TO ROADE.

The Railway, at the crossing of this road, will be in about 24 feet 9 inches cutting. The Bridge will be built at an angle of 45 degrees with the direction

of the Railway. The span of the arch will be 30 feet, upon a section taken at right angles to the Railway. The height from the rail to its soffit will be 18 feet 8 inches, and the width, the clear between the parapets, 15 feet. The body of the arch will be of brickwork, $3\frac{1}{2}$ bricks thick, and its quoins will be of stone, which will run in under the arch alternately 2 feet and 2 feet 6 inches. Each stone must be made equal to four courses of bricks on the soffit. The courses must run in a spiral direction, as shown upon the drawing; and the imposts, as shown on Fig. 5, must be cut or worked to suit the proper direction of the springing of the skew courses. The stones of the imposts must be dowelled together, and run in with lead.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM HARDINGSTONE TO OLD STRATFORD.

This Bridge is for the crossing the Railway where it is 33 feet 3 inches cutting, and must be built at an angle of $53\frac{1}{2}$ degrees to its direction. The span of the Arch will be 53 feet 6 inches upon the skew face, and its rise 8 feet 10 inches. The height from the rail to the soffit will be 26 feet 2 inches; the thickness of the arch (which will be entirely of stone) at the key will be 3 feet, and the springing 4 feet. The width, in the clear, between the parapets, 20 feet.

The Shale and Marle, marked A, upon which the rock rests, from which the bridge springs, will require to be faced with Ashlar work, extending 10 feet on each side of the bridge, and of the thickness shown upon the drawings.

An invert (B) of rough stone must be made across the Railway, between the facing walls, and extend a certain distance on each side of the bridge as shown in the drawing. The courses of stone composing the invert will be built square with the line of Railway; but the courses of stone composing the arch of the bridge will be laid in a spiral direction, as usual in skew bridges, and as is shown in Drawing No. 10, Fig. 2. The bridge for road from Ashton to Roade, and where they intersect the springing of the rock must be cut or toothed, as shown in Fig. 5, Drawing No. 10, to receive them. The whole of the remainder of the bridge will be built of stone.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ROADE HYDE TO ROADE.

This Bridge will be at a part of the Railway where it is about 35 feet 9 inches cutting, and will be square to the direction of the Railway. The span

of the Arch will be 45 feet, and its rise 10 feet: thickness of the arch at the key, 2 feet 6 inches; thickness at the springing, 3 feet; the width between the parapets will be 15 feet clear. The whole of the bridge will be of stone: the dimensions are shown upon the drawing.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ROADE TO PLANE WOODS. A.

This Bridge is upon a part of the Railway where it is about 46 feet 4 inches cutting, and will be built square to the direction of the Railway. The span of the Arch will be 45 feet 2 inches, rise 18 feet, thickness at the key 2 feet 6 inches, and at the springing 2 feet 9 inches; width between the parapets, 15 feet in the clear. It is intended to be built entirely of stone. The dimensions and forms of the various parts are shown upon the drawing.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ROADE TO PLANE WOOD. B.

Vide Plate 23.

This Bridge is in a part of the Railway where it is about 52 feet 4 inches cutting. The Arch will be a semicircle of 46 feet span, thickness at the key 2 feet 6 inches, thickness at the springing 3 feet, width in the clear between the parapets 15 feet. The bridge is intended to be entirely of stone.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM ROADE TO BLISWORTH.

This Bridge will be built in a part of the Railway where it is about 53 feet 6 inches cutting, and it will cross at right angles. The span of the Arch will be 48 feet 4½ inches, rise 18 feet 9 inches, thickness at the key, 2 feet 6 inches, thickness at the right course, above the springing, 2 feet 6 inches; width in the clear between the parapets 15 feet. The bridge is intended to be built entirely of stone. The dimensions and forms of the various parts are shown upon the drawing.

For description of materials and workmanship, see General Stipulations.

BRIDGE FOR ROAD FROM BLISWORTH TO COURTEENHALL.

Vide Plate 24.

This Bridge is on a part of the Railway where it is in about 55 feet 3 inches cutting and will be built at an angle of 56 degrees with the direction of the Railway. The Arch is to be of stone, and to be strengthened, as shown, by 4 counterforts of Ashlar work.

Span of Arch on the skew face 63 feet, rise of arch 13 feet, thickness at the key 2 feet 6 inches, thickness at the springing 3 feet 6 inches, width in the clear between the parapets 18 feet. The dimensions of the various parts are shown upon the drawings.

For description of materials and workmanship, see General Stipulations.

BRIDGE AT THE ROAD FROM TOWCESTER TO COTTON END.

Vide Plate 25.

This Bridge is on a part of the Railway where it is in about 38 feet 9 inches embankments, and will be built square to the direction of the Railway. The Wings will be built parallel to the Railway, and will be pierced with arched openings. The span of the Main Arch, 30 feet, to be composed of brick, faced with stone, which will be worked with archivolt mouldings. No stone forming the front of the arch must be less than 2 feet long, measured on the circumference of the soffit of the arch, and they must tooth into the brickwork, so that the stones may be 1 foot 6 inches and 1 foot 1 inch in length, under the arch alternately, and also on the return of the groins of the abutments, which will also be faced with stone. The arch will also be faced with stone, and have archivolt mouldings. The fronts of the pilasters must be faced with stone, in courses of not less than 12 inches in height, consisting of regular headers and stretchers. The headers must be not less than 18 inches long, and 14 inches wide. The stretchers not less than 3 feet long, and 9 inches wide.

The fronts of the Pilasters, stone facing to main and side arches, key stones, facia cornice, dentils, plinth to parapet and coping, must be smooth chisel dressed, and the beds must be made true and level. The Wing Walls will be pierced by openings, and they again will be intersected by other openings, at right angles to the former, so that the Transverse Arches will be resting upon piers only.

The whole of the details of form and dimensions will be seen upon the drawings.

For description of materials and workmanship, see General Stipulations.

FORMATION OF ROADS OVER AND UNDER BRIDGES, AND METALLING THE SAME.

Where the necessary backing to the bridges shall have been filled in, and duly completed, to within 1 foot 6 inches of the surface of the existing or intended road, then a coating (6 inches thick) of Stones, broken to a gauge ring of 3 inches diameter, shall be properly spread and levelled; and on this another coating (also 6 inches thick) of Stones, broken to a 2-inch gauge ring, shall be laid and properly levelled. This being duly performed, the traffic of the road shall be allowed to pass over the new road. And when the new material has been sufficiently consolidated, in the opinion of the Engineer or Engineers for the time being, but previous to a surface crust being formed, then a further coating of Stone or Gravel, of a size and quality corresponding with that constituting the surface of the existing roads, shall be laid, of sufficient thickness and form so as to render it in every way agreeable to the form of such existing road: due allowance being made for sinking and compressing of the loose material.

Previous to the last coating of Stone or Gravel being applied, and also afterwards, until all the works included in this contract are completed, the surface of such roads shall be kept in proper form; the ruts being filled in, and all settling from sinking and compressing made good. And if there are on the existing roads any Footpaths, then similar ones shall be made, of the same form and dimensions, and of similar materials to those of the existing roads, at the charge of the Contractor.

It being further understood, that this Metalling shall extend for the whole width between the abutments or parapets of all the Bridges, and shall be continued beyond such abutments and parapets of the width and form of the existing roads, until its junction with the line of such roads. Through the extent of all or any of the diversions, the top soil shall be removed, and the level of the surface formed, so as to rise or fall from each commencement of such diversion to the lowest or highest parts of such diversions uniformly.

The metalling and footpaths for such diversion being excavated, as hereinbefore described for the roads over or under bridges. The gravel or Stones composing the existing line of road, when it is requisite, shall be Excavated and removed, and also the fences grubbed up, and left for the use of the owners or

occupiers of such land; the vacuities and irregularities on the surface occasioned thereby, shall be levelled and made good by the soil from the new line of road, and if that is not sufficient, from the soil on the line of Railway.

The Fencing to make good to the ends of the parapets or abutments of the bridge; and for the extent of diversions, shall be executed in accordance with that hereinbefore described for the permanent fencing of the Railway; and where a ditch is not to be made, then an additional line of posts and rails shall be used in lieu thereof.

It is expressly stipulated, that in all cases wherein (in the execution of the works herein specified) any part of any carriage or horse or other Road, either public or private, shall be found necessary to be cut through, raised, or sunk, taken, or so much injured or interfered with that the same shall be rendered impassable or inconvenient for passengers or carriages, or the persons entitled to the use of such road, the Contractor shall, at his own expense, before any such road shall be so cut through, raised, sunk, taken, injured, or interfered with, as aforesaid, cause "another good and sufficient Road," as the case may require, to be set out and made in place of same; and maintain and keep the same in repair during the continuance of this Contract, or until the principal road shall be restored, and rendered as convenient for passengers and carriages as the said road to be cut through, sunk, taken, injured, or interfered with, as aforesaid, or as near thereto as may be.

And whatever Agreement the Railway Company, by their Act of Parliament, shall be liable to perform with the Trustees of any road or roads, regarding the construction of such temporary roads during the continuance of the works, or the regulating of any of these works in connexion with these roads:

It is further stipulated, "that the Contractor shall become liable for the due observance of the same;" and if he fail in this, then the amount of any fines or penalties which the Company shall become answerable for, shall be deducted from the amount of his Contract.

CULVERTS.

Vide Plate 21.

The Culverts must be built in the situations at the angle, and of the size shown upon the General Section, the form and particular dimensions to be as shown upon the Drawing No. 21.

Each Culvert must be placed so as to afford a free and uninterrupted passage for the water.

The foundations must be cut out as nearly the size of the brickwork as possible, and the vacant spaces must be punned up to the surface of the ground.

The brickwork of the Side Walls and Wing Walls must be laid on English bond, and the Arch and Invert in separate half brick rings.

The materials and workmanship, and general instructions, must be similar to that described under the head of materials and workmanship, see General Stipulations.

All Culverts exceeding 4 feet in diameter, shall be covered with Clay 2 feet above the top, and 4 feet on each side, well punned in layers of 1 foot in thickness, and at least 500 cubic yards of earth shall be placed uniformly on each culvert, before the embankments shall be allowed to come upon it.

Wherever the direction or position of the Culvert does not correspond with that of the stream, the course of the latter shall be altered, so that the water may be conducted to and from each end of the culvert, in the manner best suited for facilitating the drainage.

The clause describing "The Ballasting and Laying the Permanent Way" is similar to that specified in Contract 5 B, hereinbefore given, (vide page 71.)

EXTRA, OR CONTINGENT WORKS.

FENCE GATES.

The Fence Gates are to be made of the form and dimensions shown in the Drawing No. 26.

The heels and the heads are to be of good English Oak, sawn out to the proper dimensions, and morticed for the reception of the horizontal bars.

The horizontal bars are to be five in number, of cleft oak, and smoothed over. The ends must fit the mortices of the heels and heads, and be secured by oak pins.

The diagonal Braces are to be similar to the bars, to which they must be firmly nailed. The nails to pass through both, and have their points clenched.

The posts to be of oak, the top sawn to the dimensions and form, with a small cap on each. That portion of the post to be placed under the surface of the ground to be charred.

The gate irons shall be of the form shown in the drawing.

The gates must be firmly fixed in the line of the quicksets, and the wood railing neatly joined to the gate posts.

The gates and posts must be painted with two coats of white or stone coloured paint.

EXCAVATIONS AND EMBANKMENTS OF SLOPED OCCUPATION ROADS.

These Excavations and Embankments are to be made in the same manner as those upon the line of Railway, and with Slopes, as may be directed by the Engineer. The contents of the excavations shall be conveyed to the nearest embankment upon the line of Railway, or to the nearest spoil bank.

The Embankments are to be formed with the surplus materials in the excavations upon the line of Railway, should such exist, but if not, they must be made with material obtained from one or more of the excavations upon the line of railway (as may be fixed by the Engineer) by altering the slopes so as to afford a sufficient supply; and the Contractor shall be paid for the same at the rate specified in the Schedule of prices.

But whenever there is a surplus of materials, the Contractor shall employ the same in forming the Approaches to occupation bridges or sloped roads, should such be required, and the cost of so employing it shall be considered a part of his Contract, to which the stipulations and prices for extra works do not apply.

METALLING OCCUPATION BRIDGES.

This is to be done in the manner as described in the specification of formation of roads over and under bridges, and for diversions.

PAVING CROSSINGS.

All the roads crossing the Railway without bridges are to be paved in the manner shown in the Drawing No. 25, with good 6 or 7-inch paving of Leicester granite, or other granite equally good. The Paving must be laid on a bed of fine clear gravel of 12 inches in thickness, in a solid and substantial manner.

The paving Stones must be cubes as nearly as possible.

Each rail must be protected by two iron Bars, as shown in the Drawing No. 25; they will be considered as part of the rails, and will be provided by the Company.

OCCUPATION BRIDGES.

Those under embankments are to be similar to that at the road from Bozenham Mill to Hartwell, Drawing No. 5.

Those over cuttings to be similar to that for road at 1 mile 22 chains, Drawing No. 9. It being understood that the specification for the above bridges referred to are to apply to the occupation bridges.

CULVERTS.

The Culverts are to be built in the same manner as those previously described in the former part of the Specification; they are to be built of the forms and dimensions shown in Drawing No. 21, the sizes being selected to suit the particular situation.

LAYING AND BALLASTING PERMANENT SIDINGS.

The Sidings are to be laid in such positions and of such lengths as may be directed by the Engineer. They must be laid in form and manner shown in Drawing No. 22.

The Contractor will be required to take up any part of the rails previously laid that may be found necessary; to cut them into their proper lengths for the reception of other iron work, to relay them, and to fix all the necessary crossing plates, check rails, moveable points, or sliding rails, with the requisite machinery for moving them.

The whole must be made equally as firm and substantial as the other parts of the permanent way.

The Specification of the Permanent Ballasting already described must be considered equally applicable to the construction of the Sidings.

TIME OF COMPLETION.

The whole of the Works in this Contract are to be completed within the space of two years from the date of signing this Contract, and the Contractor shall be bound to uphold and keep in good order the whole of the works for the space of one Year after the works shall have been so completed.

RATE OF PROGRESS.

At or before the 22nd day of October, 1835, the Excavations, Nos. 1, 2, 3, and 4, referred to in the aforesaid Specifications, plans, section, and drawings, shall be performed and completed. On or before the 22nd day of October, 1835,

not less than 70,000 cubic yards shall be excavated at the situation marked with the letter A in the Cutting No. 5, and referred to in the said specification, and removed to the embankment or embankments as is directed in the aforesaid specification. On or before the 22nd day of April, 1836, not less than 70,000 cubic yards shall be excavated at the situation marked with the letter I, in Excavation No. 5, referred to and described in said specification hereunto annexed, and removed as aforesaid; and after the 22nd day of April, 1836, at the situation marked with the letter I, in Excavation No. 5; and after 22nd day of October, 1835, at the situation marked with the letter A, in Excavation No. 5, each described and referred to as aforesaid. The said (Contractor) shall excavate and convey to the several embankments not less than 25,000 cubic yards per Month, at each and every of the aforesaid places in each and every of the following months of April, May, June, July, August, and September; and also 20,000 cubic yards at each and every of the above places as aforesaid, for each and every of the following months of October, November, December, January, February, and March, until the completion of the said excavation; it being proposed that, under this arrangement, the whole of the excavations and embankments contracted to be executed by the said (Contractor) under this Contract, shall be completed and finished within two Years and a half from the date of the same Contract, all which said places and works are mentioned in the said specification hereunto annexed.

KILSBY TUNNEL.

Vide Plate 31.

The formation of this Tunnel has been found more difficult than was anticipated. It is 2398 yards in length, and is the most formidable undertaking on the line; having cost from £125 to £130 per lineal yard, which great expense was incurred in pumping, a quicksand being found to extend over about 450 yards of its length. The brickwork is principally 2 feet 3 inches in thickness, and is executed in Roman, or otherwise in metallic, cement. It is divided into three lengths by two large ventilating shafts, each of 60 feet diameter. They were carried down to the necessary level in four bricks thick, in cement, by a system of underpinning, and in lengths from 6 to 10 feet deep at a time.

WATFORD TUNNEL.

SPECIFICATION.

THIS Tunnel commences in the Merton College Estate, in the township of Cashio, in the parish of Watford, and terminates in the estate of the Earl of Essex, in the parish of Lees, or Abbott's Langley; the length is 78 statute chains; its other dimensions, precise situation, and the construction of its several parts, are minutely described, delineated, and set forth in the Plan and Section of the Railway, and in Drawings Nos. 40 and 41. The area of ground above the Tunnel, to which the Contractor must confine his operations on the surface, is 1 statute chain in width for the whole length of the tunnel. The whole space along the top of the tunnel, 1 chain in width, is to be fenced off on both sides with the temporary Fencing, which must be made to unite with the other fences, either temporary or permanent, at the ends of the tunnel. These temporary fences are to be removed after the completion of the Tunnel, and no permanent ones to be erected in their stead. All the general stipulations in the Specification, with respect to the extension of land, &c., are applicable to this part of the Contract, where no special directions are given.

The Tunnel is to be composed of a Brick Arch, nearly semicircular, supported by curved side walls standing on stone footings or skewbacks, which are to rest on the counter or inverted arch forming the base of the tunnel. The ends of the tunnel will be made with wing walls, as shown in the drawings.

A cast iron Plate is to be built into the arch, near the mouth of the tunnel, and connected by bolts to a second similar plate built into the arch, 100 feet distant from the first plate.

MATERIALS.

All the Bricks used in the Tunnel, the mouths of the tunnel wing walls, and all the shafts, must be good, sound, well-burnt, hard grey-stocks. The freestone shall be Bramley Fall, or other stone equally good, perfectly sound, and free from

flaws. The cast iron and wrought iron must be of the best quality. The strength of the wrought iron bolts and their couplings must be proved by their being subjected to a chain of twenty-five tons each, before being used in the tunnel.

The Mortar to be used in the Tunnel shall be made with the best fresh-burnt Merstham or Dorking lime, or other lime which the Engineer may deem equally good. It shall be ground under edge-stones in its dry or unslaked state. The sand must be sharp clean sand, and shall be mixed with the lime in the proportion of three measures of sand to one of lime.

The Lime and Sand must be well mixed and worked with a proper quantity of water through a pug-mill, as required for use.

The Contractor shall sink six working Shafts on the centre line of the tunnel, at convenient distances. They shall not be less than 8 feet diameter within the brickwork, which shall be of the thickness of one brick length.

Each shaft shall be of the same diameter from top to bottom, perfectly cylindrical, free from bulges and other distortions. The brickwork shall be laid in two half-brick rings, with the joints properly broken, and flushed in solid with mortar. The bricks must be moulded to fit the circumference of the shaft.

Where each shaft intersects the top of the arch of the Tunnel, a cast iron curb or ring of the same diameter as the shaft shall be inserted in the brickwork of the arch, and upon which the shaft must be built. No wood curbs will be permitted to be used in the brickwork of the shafts.

The Contractor must sink an Air Shaft at the distance of 50 yards on each side of each working shaft, unless the said distance of fifty yards shall fall in any road; in which case, the air shaft must be sunk as near thereto as practicable.

The Contractor will be at liberty to sink as many other air shafts as he may think proper. The diameter of these shafts must not be less than 3 feet 6 inches within the brickwork. At their intersection with the brickwork of the arch of the tunnel, they must stand upon cast iron curbs, exactly similar to those specified for the working shaft; and the air shafts must, in every particular, except as to their diameter, be made in the manner hereinbefore specified for the working shaft.

After the completion of the Tunnel, the brickwork of the working and air shafts must be carried up to a height of 10 feet above the surface of the ground, and finished with a coping stone 6 inches thick at the inner circumference, and $4\frac{1}{2}$ inches at the outer circumference. The width of the coping is to be 15 inches, projecting 1 inch on the outside of the brickwork, and throated.

When any water may occur in sinking, it must be completely excluded from the shafts or tunnel by a lining of puddle behind the brickwork of the shafts, or

by laying the brickwork in Roman cement, or by the adoption of any other means which the Engineer may consider necessary.

The Arch and Side Walls are to be two bricks thick; the invert, one brick and a half thick throughout the whole length of the tunnel, unless the stratum through which the tunnel shall pass, should, in the opinion of the Engineer, require either a greater or a less thickness of brickwork in any part of the walls of the tunnel.

Whenever required to do so, the Contractor shall make the brickwork of the tunnel in any part thereof, of such thickness as the Engineer may direct.

The Contractor is to be paid for any increase in the quantity of brickwork or excavation, and he is to be charged for any decrease at the rate specified in the Schedule.

The counter-arch, or invert, of whatever thickness it may be, shall be carefully laid and bound. The side walls shall be laid in English bond.

The arch, if of the thickness of one brick and a half, shall be built or composed of three several half brick rings, if of the thickness of two bricks, it shall be built or composed of four several half brick rings, and so on, and each half brick ring shall contain five courses of bricks more in number than the inner one immediately preceding it. The footings or skew backs of the side walls shall be made of Bramley Fall stone, or other stone equally good for the purpose, and of the sectional form shown in the drawing.

The length of each stone must not be less than 3 feet. There must be a bed of brickwork under the stone footing or skewback, extending from the inverted arch, as shown in the Drawings. The skewback must be well bedded in the brickwork.

The mortar used in the brickwork shall be as little in quantity, and as uniform in thickness between the joints, as is consistent with making the work firm and solid throughout, the longitudinal courses must be laid perfectly straight, in the direction of the tunnel, and must be parallel in every direction with the surface of the rails.

If at any time before the termination of the Contract, the regular continuity of the brickwork of the tunnel should be destroyed, arising either from irregular shrinking or settlement of the arch, or imperfection in the centres, or any other cause whatsoever, the Contractor must remove and amend the irregularities in a satisfactory manner.

Whenever water may occur, or flow into the tunnel, and it may be deemed expedient by the Engineer to lay any part of the brickwork in the best Roman

cement, the Contractor shall be paid for so doing, such an additional sum per rod of 306 cubic feet as may be stated in the Schedule of prices.

EXCAVATION.

In no case shall the excavation be carried more than 6 feet in advance of the brickwork; and should any change in the strata occur, which may, in the opinion of the Engineer, require the distance to be reduced, the Contractor shall regulate the distance by the directions of the Engineer.

In making the excavations, great care must be taken that they do not exceed the area necessary for the reception of the brickwork; but such may unavoidably be the case. The vacant space between the sides or roof of the excavation and the brickwork of the tunnel shall be filled in with chalk, broken small, and rammed in hard and solid with beaters, so as effectually to prevent any distortion in the form of the tunnel from irregularity of pressure.

The foundation for the reception of the invert or counter arch shall be cut out of the exact form and depth required, before any part of the brickwork of the corresponding portion of the tunnel shall be laid; and if any faulty places shall occur in the chalk or other stratum forming the floor of the excavation, the faulty places must be made good by being filled up.

Whenever the faces of the excavations, carried on by means of two contiguous shafts, shall approach within 50 yards of each other, the Contractor shall then drive a heading quite through, and join the workings before he proceeds with the erection of any more of the brickwork of the tunnel.

No shaft whatever shall be permitted to be sunk in any public or private road which may cross the line of the tunnel.

About 1700 yards of the excavation from the tunnel will be required for the embankment over the Colne Valley, and the whole of the remainder will be required for the embankments beyond the north end of the tunnel; all the material which shall be excavated from the tunnel, whether brought out at the ends or taken up the shafts, must be conveyed into the embankments at the ends.

In the execution of this part of his Contract, the Contractor shall provide all the necessary materials and machinery for executing the work; make all the necessary shafts, bore holes, and perform every operation necessary for completing the work in the manner intended in the Specifications. All the machinery, centerings, &c., must be constructed in such a manner as the Engineer shall approve. Any damage done to the land by the falling of the surface during the execution of

the work, shall be paid for by the Contractor. Marks and signals will from time to time be given to the Contractor by the Company's Engineers, for the purpose of regulating the direction and level of the tunnel; and the Contractor shall be at the expense of erecting any temporary or permanent marks or signals which may be considered necessary for giving the direction and levels with the required accuracy. The slopes of the ground over the ends of the tunnel are to be made at an inclination of one to one, and a ditch must be formed at the top, similar to those at the tops of the excavations, and must communicate therewith. The slope must be made with puddle, as shown in the Drawing. A cast iron drain, as shown in the Drawing, is to be laid in the bottom of the tunnel, midway between the two lines of Railway, and through the whole length of the tunnel. The connexions of the several pieces must be properly and accurately made, and the drain must communicate with the side drains of the excavations by two cast iron side branches at each end.

RAILWAY TURN-TABLES.

Vide Plates 34, 35, 56, 57, and 58.

THE Turn-table consists of a circular table furnished with rails, which is secured to a strong centre moveable pivot, and the table rests at its extremities upon small rollers. The pivot turns in a socket properly prepared to receive it, and the latter is borne upon cast iron arms extending from the centre to a circular iron plate, which also serves as a curb for the rollers to run upon. The lower curb frame is founded on brickwork; and in the case of a turn-table being required on an embankment, it is necessary to carry the bearing walls down to the solid ground.

The Turn-tables on railways are sometimes made sufficiently large to take an engine and tender upon the platform together, by which much time is saved, as that upon the London and Greenwich Railway at Greenwich. These large ones are turned by means of a rack and pinion, instead of by the mere leverage obtained by pushing the vehicles to the position required.

SPECIFICATION OF 12 FEET TURN-RAILS.

Vide Plates 34 and 35.

The Turn-rails are to be 12 feet in diameter, and all of cast iron, except where otherwise described.

The Table is to be hung to and turn upon a centre Pivot, marked A upon the drawing, and 8 cast iron Rollers, B B, which work upon wrought iron Arms, C C, radiating from a wrought iron Hoop, D, the whole working round the centre Pivot.

The whole table is to be enclosed by a cast iron Ring, E E, 12 feet 7 inches in diameter on the outside, and 1 foot $8\frac{1}{2}$ inches deep. Upon this Ring the circular Rail, F F, is to be cast for the rollers to work upon; the centre diameter of this Rail to be 11 feet 3 inches, and its width $1\frac{1}{2}$ inches.

The outside Ring is to be cast in two parts, and bolted together by means of flanches and screw bolts three in number, each 1 inch diameter, on each side, as shown in the drawings at G G. The section of Ring is shown in the drawings, with the respective thicknesses marked thereon.

The top, or Table, consists of four principal Arms, marked I I, traversing the tables at right angles, 9 inches deep at their centres, and $6\frac{3}{4}$ inches at their ends. Also four Arms radiating from the centre piece to the corners formed by the others; these Arms are marked K K in the drawings, and are $8\frac{1}{4}$ inches deep at the centre piece. Holes $\frac{3}{4}$ of an inch diameter are to be cast in the first named arms, for fastening the Railway bars or Rails to the table. At the extremity of these arms is the circular Rail M M, for working or bearing upon the rollers; its centre diameter being 10 feet $3\frac{1}{2}$ inches, and its width 2 inches; the Section of which, with the respective thicknesses marked thereon, is shown in the drawings.

In the centre piece four Holes are to be cast for receiving $1\frac{1}{4}$ inch screw bolts, for hanging the table to the centre pivot. The space between the principal arms are to be left open, and the Grating to be of the shape shown in the drawings, and to be put on afterwards.

The table to work upon eight cast iron Rollers, B B, of the shape shown in the drawings, and 10 inches diameter; to have a hole bored out in their centres for a $\frac{3}{4}$ of an inch rod to work in freely. The periphery of each roller to be turned. These rollers to work between two wrought iron Hoops, P P, five-eighths of

an inch thick and two inches deep, and made in two parts; and upon eight wrought iron Arms, C C, $\frac{3}{4}$ of an inch diameter; each of these arms to be screwed into the hoops, and a nut, Q Q, screwed up tight against them. The other extremities of these arms are to be screwed into another wrought iron Hoop, D D, 2 inches deep, and 1 inch thick: the inside diameter of this hoop to be 5 inches, and to be turned, so as to work round the collar on the centre pedestal R. The Collar for the hoop D to work upon must be turned.

The centre Pedestal is to be of cast iron, having a Hole, 3 inches diameter, and 5 inches deep, bored out of its centre. A brass Step, S, 2 inches thick, is to be put into the bottom of this hole, for the pivot to work upon; four Holes, 1 inch diameter, to be cast in the feet of the pedestal, for fastening it to the stone block. The centre pivot, A, is to be of cast iron, 13 inches long, including the head, which is to be 1 inch thick, and 10 inches diameter, with four holes, each $1\frac{1}{4}$ inches diameter; that part of the Pivot working in the pedestal to be 3 inches diameter, with a rounded end, as shown in the drawings, the working part of the Pivot is to be turned: the remaining part of same to the underside of the head, is to be four inches diameter. A Hole, V, is to be cast in a slanting direction, down to the Pivot, for the supplying of oil to its working parts, so that it shall run into the pedestal at the side of the pivot.

The table is to be hung to this pivot by four screw bolts, each $1\frac{1}{4}$ inch diameter, in such a manner that the table may be eased off or lowered on to the rollers at pleasure. The heads of these Bolts to be counter-sunk into the centre piece, as shown in the drawings. On the surface of the table two Lines of Railway must be fixed, at right angles to each other; the distance between the rails inside to be 4 feet $8\frac{1}{2}$ inches. The bars or rails, W W, are to be of wrought iron, 3 inches broad, and 2 inches thick, and of the shape shown in the drawings; bolted to the principal Arms with $\frac{3}{4}$ of an inch screw bolts, the heads being counter-sunk into the rails. Four sets of wrought iron Inclined Planes are to be fixed at the intersection of the rails, for the flanches of the wheels to run upon when passing the openings. A Latch, X, is to be fixed to the table, and two Catches, Y, Y, are to be cast on the outside rim at right angles to each other, for holding the table in the required position.

The whole of the materials and workmanship to be of the best possible description, and the Contractor is to uphold all the several parts for the space of six Months, replacing any unsound castings, or imperfect workmanship.

The Company's Engineer, or any person whom he may appoint, may reject any Turn-Rail, or part of one, which he may think is not sufficiently sound.

N.B. The top, or table, may be cast in two parts.

SPECIFICATION FOR A FIRST-CLASS COACH,

FOR THE LONDON AND BIRMINGHAM RAILWAY.

THE BODIES.

EACH coach is to consist of three bodies or compartments, as represented in the annexed Drawing, Fig. 1, the extreme length, outside measure, being 15 feet 6 inches; the length of each body 4 feet 11 inches, the breadth 6 feet, and the height from floor to roof 4 feet 6½ inches, all inside measure, and exclusive of stuffing. The frame-work of the bodies must be made of well-seasoned ash, of the following dimensions: for the bottom sides 2½ inches by 4½ inches; standing pillars at the corners and doorways (twenty in the three bodies) 2½ inches, with a sweep 3 inches at the widest part, and the turn-under 2½ inches, the standing pillars in the doorways being strengthened at the bottom by uprights of birch, firmly screwed to the seat rail; the top rails 2½ inches by 1½ inch; cross bars for the two ends (four in each) 2¼ inches by 2 inches, with battens of ash between, 2½ inches by 1½ inch, and not less than twelve of them at each end; the cross-bars across the divisions (one for each) 2½ inches by 1 inch; the seat rails (ten in three bodies) 1½ inch by 2½ inches; the hoop sticks to support the roof (four in the two end bodies, and three in the middle body) 2¼ inches wide by 1 inch and 5-8ths thick; the sides to be battened with ash of the same strength, and in the same manner, as the end of the coach; the flooring of American pine, 1¼ inch, plated underneath with three strap plates of wrought iron, 1½ inch wide by a ¼ of an inch thick from end to end, secured by about one hundred clip-headed bolts and nuts; the divisions between the bodies of the same ¾ of an inch thick; seat-boards of the same, also ¾ of an inch; the roof of the same, also to be ¾ of an inch; to be covered with three hides, weighing not less than thirty-eight pounds each, protected on the top with ribs of ash screwed on, 3 inches apart, 2¼ inches broad by 5-8ths of an inch thick. The roof to be bound with a beading of ash

$1\frac{1}{2}$ inch square, screwed on and projecting, so as to allow of the rain to drop clear of the panels; to be channelled, and to stand somewhat higher over the doors; seats, E, at both ends of the roof, to hold two persons on each, with iron seat rails, F; three steps, G, on each side, and two iron handles covered with leather at each end to mount; and a foot-board of birch, H, supported underneath with iron stays. The roof, for the space of 8 feet 6 inches, to be fenced along and across with luggage rails, D, 5-8ths of an inch in diameter, of iron, supported at intervals with uprights, $4\frac{1}{2}$ inches high, and an oiled canvas luggage sheet, with straps complete, of dimensions sufficient to extend over the same. The whole of the exterior of the coach to be panelled with well-seasoned panel board, the upper quarters, B, $\frac{1}{2}$ an inch thick, lower quarters, A, 5-16ths of an inch thick, and ends $\frac{1}{2}$ an inch, C, Fig. 3; the panels, before being fixed, to be covered with canvas, glued on, and when fixed, which must be done with copper sprigs, 1 inch apart, they must have glued on them a second lining of canvas. The mouldings to be of brass, and blacked if required. Brass door and side handles; two lamp irons to each coach, and two large-sized lamps, upon an approved principle. The windows (two in each body) to be of good plate glass, $22\frac{1}{2}$ inches by 19 inches, and not less than 5-16ths of an inch thick; and the frames to be made of well-seasoned oak, $1\frac{1}{2}$ inch broad, and to be covered with strong black velvet, or painted, filled up, pumiced, and varnished, as may be required; small leather pads, stuffed with horsehair, to be put at the bottom of the glass stop, for the glass to fall upon when let down. The painting to consist of three coats of white lead or colour, and four coats of filling up; after being pumiced, the body to receive three more coats of the same colour, and is then to be finished with two coats of a colour to be approved of by the Directors; the upper quarters are to be painted black in like manner, and the whole body is to be varnished with four coats of the best varnish. The panels are to be lettered in gold, and ornamented in the centre with a coat of arms or other device. The insides to be lined throughout with drab cloth, of a quality worth at the present time 12*s*. 6*d*. per yard, of 60 inches wide, the quantity required for the three bodies being about 38 yards. Lace (seven dozen for the three bodies) 18*s*. per dozen; seaming ditto (twelve dozen) 3*s*. 6*d*. per dozen; pasting ditto (four dozen) 3*s*. 6*d*. per dozen; holders of lace and glass strings of the same, lined with strong leather hat strings, and the floor to be covered with the best Brussels carpet. The backs and cushions to be stuffed with the best curled hair, the quantity required for the three bodies being about one hundred and twelve pounds. The seats to be divided into four arms in each body, fixed on with iron corner plates and screws,

and finished with broad mahogany tops, varnished; each seat also to be numbered with a japan label, with gilt figures. The bodies to be firmly fixed upon the under carriage, with strong bolts secured with nuts; the whole of the workmanship to be strong and substantial, equal in every respect in style and execution to that of the coaches the most recently built by the Liverpool and Manchester Railway Company, at their yard in Crown Street, Liverpool. The whole of the iron work to be of the best quality, the weight of that portion attached to the bodies, consisting of luggage rails, steps, bolts, foot-boards, stays, &c., being about one hundred weight one quarter and twenty-four pounds. Screws to be used throughout instead of nails.

UNDER CARRIAGE FRAME.

The plan of the under carriage frame will be seen by the annexed Drawing, Fig. 2: its extreme length is 15 feet 8 inches, the buffers extending 1 foot 9 inches beyond at each end. The whole must be made of well-seasoned ash, of the following parts and dimensions:—The carriage sides, Fig. 1, I, (two on each side, but they may be made in two pieces, spliced in the middle, and fitted with iron bolts and nuts,) must be 3 inches square, coupled together vertically by wrought-iron props, Fig. 1, K, and corner plates, eight of the former in each carriage weighing two quarters twenty-five pounds, and four of the latter weighing two quarters eighteen pounds. The ends of the carriage, Fig. 3, consist of two pieces of ash, L, at each end, extending from side to side (6 feet 1 inch), $3\frac{1}{2}$ inches wide by 3 inches thick, and swelling to $11\frac{1}{2}$ inches at the deepest part, morticed together as in the sides, only with three upright blocks, M, of ash instead of iron. The frame is strengthened by four diagonal, Fig. 2, N; two centre longitudinal, O; and two centre cross-stays of ash, each 3 inches by $2\frac{1}{2}$ inches, extending from the lower carriage, side morticed into a solid piece of ash, Q, in the middle of the frame, 2 feet 3 inches by 1 foot 4 inches, and 3 inches thick, secured thereto, as well as to the carriage sides, by strong angle plates of wrought iron, and plated at the corners with wrought iron, 3-8ths of an inch thick, $2\frac{1}{4}$ inches wide, fixed on with $\frac{1}{2}$ inch bolts and nuts. The two centre longitudinal stays, the two centre cross-stays, and the whole of the lower carriage side, Fig. 1, F, must be plated throughout on one side with wrought iron, 3-8ths of an inch thick, $2\frac{3}{4}$ inches wide, and fixed in the same manner as the corner plates, with bolts and nuts. The weight of the plating will be about two hundred weight and twenty pounds, and that of the bolts and nuts (about 350 of each) one hundred two quarters. There must be four axle guards, Fig. 1, R, of

wrought iron, tapering from $\frac{3}{4}$ of an inch to 5-8ths of an inch thick, firmly fixed to the carriage sides by bolts and nuts, in exact square with each other, at the distance of 8 feet 6 inches from centre to centre. The steps, S, consisting of eighteen, and weighing about one hundred two quarters and twenty-two pounds, having a tread of 12 inches by 9 inches, must be fitted in like manner to the carriage sides. There must be eight wrought iron roller boxes, weighing, with rollers for the same, three quarters of a hundred weight; these are to be screwed under the under part of the carriage sides, for the extremities of the sides or bearing springs to rest and work upon.

BUFFERS AND DRAWING APPARATUS.

There are in each carriage four large buffer rods, Fig. 1, T, of wrought iron, weighing two hundred one quarter and six pounds, with a butt end of ash, U, 14 inches diameter, covered with stout leather, and stuffed with horse-hair; these rods abut upon two large springs, Fig. 2, V, having fifteen plates, each of $\frac{1}{4}$ inch steel, 3 inches broad, and, when fixed, 5 feet 9 inches long; there are also two drawing springs, W, with six plates, each of steel, of the same dimensions, and 3 feet long, the weight of the four springs being three hundred weight and twenty-five pounds. These are fitted into a groove, X, which is firmly bolted upon the slab of ash in the centre of the frame, with liberty to work to and fro for the space of $2\frac{1}{2}$ inches. The iron-work connected with the buffer and drawing apparatus (besides the buffer rods already described) consists of draw-rods and plates, Y, attached, weighing three quarters and twenty-two pounds; four square socket rings and buffer plates, Z, weighing two quarters and eighteen pounds; one grove plate, *a*, two side plates, and two edge plates, weighing two quarters and six pounds. The weight of sundry small iron-work about the under frame, not enumerated, may be estimated at three quarters of a hundred weight.

The whole of the steel for the buffer and draw-springs, as well as for the bearing-springs hereafter described, to be well tempered and of the best quality, and all the iron to be also of the best quality, well and neatly wrought, filed, and fitted; the framing to be firm and substantial, and to be constructed according to the most approved mode adopted in the recently-built carriages on the Liverpool and Manchester Railway. The carriage to be painted with five coats of paint, of the colour corresponding with that of the bodies, to be neatly picked out, and finished with two coats of the best varnish. There must be three chains at each end of the carriage, about 18 inches long, with an open link with a bolt and nut at one end, and a strong hook at the other; the centre chain, being the one

by which the carriage is drawn, must be rather stronger than the other two, which are only for additional safety. The weight of the six chains may be about one hundred weight six quarters.

BREAK.

As it is not necessary that every carriage should be provided with a break, this must be considered an extra, and a separate Tender made for it accordingly. It consists of a number of levers, tooth and pinion wheels, &c., the application of which can only be understood by inspection or detailed drawings. It acts on both sides of the two wheels on the same side of the carriage simultaneously. The whole of the apparatus will be about four hundred weight.

WHEELS, AXLES, AXLE BOXES, AND SPRINGS.

The wheels must be made with the rim and spokes of wrought iron, and the nave of cast iron, of a plan and construction to be approved of by the Engineer. The outer rim or tire to be tapped on the inner rim with not less than eight screw-bolts and nuts in each wheel. The axle to be made of the best rolled or wrought iron, 3 inches diameter in the centre, and $3\frac{1}{2}$ inches where it passes through the nave, to be turned down to 2 inches and 5-8ths, for an outside bearing of $4\frac{1}{2}$ inches long, which must be case-hardened. The wheels to be firmly keyed on the axle with a 5-8ths of an inch key, according to a guage, and the tire to be turned to a template, to be furnished by the Engineer, and to be painted and picked out with one coat of paint and a coat of varnish. The weight of the four wheels and two axles is about eighteen hundred weight. The axle boxes, Fig. 1, *b*, which are of cast iron, must be fitted up with brass steps to suit the journals, and to be of the best quality. Upon the axle boxes are fixed the side or bearing springs, Fig. 1, *c*, of which there are four, having each twelve plates, $\frac{1}{4}$ inch steel, 3 inches wide, and when weigh-led are 5 feet long; the weight of the four is about three hundred weight one quarter and fourteen pounds.

RECAPITULATION OF THE IRON WORK.

	Cwt.	qrs.	lbs.
Luggage rails, lamp irons, and other body work	2	1	4
Eight iron props between upper and lower carriage side	0	2	25
Four corner plates at each corner of under carriage	0	2	18
The plating under the carriage sides and centre	2	0	20
About three hundred and fifty bolts and three hundred and fifty nuts	1	2	0
Four large buffer rods	2	1	6
Two buffer springs and two draw springs	3	0	25
Draw rods and plates attached	0	3	22
Four square socket rings and buffer plates	0	2	18
One grove plate, two side ditto, two edge ditto	0	2	6
Four axle guards	1	1	19
Six draw and safety chains	1	2	0
Four side or bearing springs	3	1	14
Eight roller boxes and rollers	0	2	13
Eighteen steps	1	2	22
Sundry iron work about the under frame, not enumerated	0	3	0
Axle boxes and brasses	1	2	0
Wheels and axles	18	0	0
Break apparatus	4	0	0
Total weight of iron work in each carriage	47	3	16

A model of the proposed carriage may be inspected at the office of the London and Birmingham Company, No. 83, Cornhill, and a full-sized pattern coach may be seen, and all other particulars had, on application to Mr. Woods, at the Company's office, India Buildings, Liverpool. The weight of the iron work, and the dimensions of the wood work, are furnished in the foregoing Specification, in order to facilitate the calculations of coachmakers and others who may be disposed to contract with the Company; but it is clearly to be understood that in all matters relating to the mode of construction the fittings, finish, arrangement, or design, reference is to be had wholly and entirely to the full-sized pattern coach, which will be exhibited in Liverpool, and not to the model in London, or to the above description or the accompanying Drawing; and it must

be further understood, that the Contract is to be completed to the satisfaction of the Engineer of the Company, or of any other person appointed by the Directors to inspect and pass the work.

The carriages must be delivered at the Company's Station, at Euston Grove, London, or at their Station in Birmingham, at the option of the Directors, not later than the day of 1847.

GRAND JUNCTION RAILWAY.

JOSEPH LOCKE, Esq., Engineer.

This Railway obtained the Act for its construction in the month of May, 1833. The line was laid out with a view to avoid unnecessary expense; the gradients are consequently not equal to those of some other lines. It commences from the Birmingham Station of the London and Birmingham Railway, and communicates with the Liverpool and Manchester, per Warrington and Newton. The distance from Birmingham to Warrington is 78 miles, and to Newton 82·63 miles, or from Birmingham to either Liverpool or Manchester 97·50 miles. The average cost per mile is stated at £23,102.

The standard guage of way, or 4 feet 8½ inches, is employed; with Inter-spaces 6 feet in width, Side-spaces varying from 2 feet 9 inches to 3 feet 3 inches at the stations, and 6 feet 6 inches and 7 feet 9 inches at the other parts of the line. Parallel rails are laid down, set on chairs and upon blocks and sleepers, according to the usual practice.

Vide Plates 42, 43, 44, and 45.

Plate 42 represents the Aqueduct for the Duke of Bridgewater's Canal at Preston Brook, which is built entirely of stone. The backing of the arch is covered with milled lead, 7lb. to the foot superficial, at the points marked A, A, A, A, to prevent the water percolating through the stone work. This plan has been found to answer the purpose admirably, as I have heard the celebrated Engineer state that no signs of the canal can be traced from beneath the bridge.

There are several bridges of the same character as that described in Plate 43, of one, two, three, and more similar arches, some of which occur upon the skew.

GREAT WESTERN RAILWAY.

I. K. BRUNEL, Esq., Engineer.

Vide Plates 46, 47 and 48.

The Act for the Great Western Railway was obtained in August, 1835, and the works were shortly after commenced. Mr. Brunel, like the celebrated Engineer of the London and Birmingham Railway, adopted low gradients in preference to steep ones, together with slight curves, and, with the exception of the Wootten Basset and Box Planes, none of it is steeper than 1 in 344 or 15·35 feet per mile, and the curves are generally about 4, 5, or 6 miles radius. The Wootten Basset incline is 1 mile 29·09 chains in length, and the Box, which passes through a tunnel, is 2 miles 30·15 chains, and each of these planes is laid at 1 in 100 or 52·80 feet per mile.

The Box tunnel is 1¾ miles in length, and is carried through the oolite rock. The cost is estimated at upwards of £100 per yard, although only partially lined. It is 27 feet 6 inches wide at the invert, and 30 feet at a height of 7 feet 3 inches above it, the clear height from the surface of the rails being 25 feet. The parts which are lined consist of seven half brick rings at the sides, six at the arch, and four at the invert, and the foundation is 36 feet deep. The depth of cutting at the Eastern end of the tunnel is 69 feet 6 inches to the level of the rails, and it is 64 feet at the western.

This line is the parent of the *Broad guage*, the width between the rails being 7 feet, Intermediate-spaces 6 feet 6 inches and 4 feet 9 inches Side-spaces, on embankments, making a total of 30 feet. The cuttings are 38 feet wide at the level of the rails. The arches of the Bridges over the railway are 30 feet span, and about 18 feet 6 inches high, and the bridges carrying the railway are generally about 30 feet between the parapets.

The Permanent way of this railway is constructed somewhat in the form of a framing, longitudinal pieces of half timbers, or 12 inches by 6 inches are laid

under each rail; these are connected together by cross beams, having a scantling of 6 inches by 4 inches, and the latter are dovetailed and bolted to the former. The rails are of the form denominated *Bridge rails*, and weigh from 44lbs. to 62lbs. per lineal yard: the latter is found no more than sufficient for the traffic, they are fastened down to the beams on each side by screw bolts.

Some of the earthwork on this line is very heavy. The cutting eastward of the Box tunnel is calculated at 1,533,000 yards, consisting of corn brash, forest marble, and great oolite; the average depth of it is about 30 feet, with slopes varying from vertical to $1\frac{3}{4}$ to 1, and it is about $2\frac{1}{2}$ miles long. The average price of the earthwork throughout the line is said to be 19*d*. per cubic yard, and the cost from £40,000 to £44,000 per mile.

SOUTH EASTERN RAILWAY.

WILLIAM CUBITT, Esq., Engineer.

This line branches off from the London and Brighton Railway at Reigate, and passes, *via* Tonbridge, Ashford, and Canterbury, to Folkstone and Dover; there are also branches from Canterbury to Ramsgate and Margate. The distance from the Terminus at London Bridge to Dover is 87 miles 43 chains, or 66 miles 22 chains from Reigate. The first Act of Parliament was obtained in June, 1836, but the undertaking has received many amendments by subsequent Acts. The whole of the Railways connected with the London Bridge Terminus are laid down upon 4 feet $8\frac{1}{4}$ inches guage. The ruling gradient is 20 feet per mile, and it is the same upon the London and Brighton Railway.

The Engineer estimates the cost of the works as follows:—In the Godstone district, including the Bletchingly Tunnel, which is 1080 yards in length, at £17,948 per mile, the works not being particularly heavy.

The Tonbridge district, comprising the Leigh cutting and the river Medway embankment, containing upwards of half a million cubic yards each, cost £19,180 per mile.

The Dover district, which abounds in difficult undertakings, both tunnels and earthworks, &c., he states at £32,615. A double line of tunnel is constructed through the chalk, each 13 feet wide in the clear, 19 feet high to the springing of the arch, which is pointed, and 30 feet to the apex; the pier separating them is 10 feet in thickness.

BRIDGE OVER THE RAILWAY AT TUDELY.

Vide Plate 49.

The archway of this Bridge is 30 feet span, and of a novel description. The faces of the arch are turned in brickwork, but the remaining portion is formed with three cast-iron plates bolted together, extending to a certain distance along the crown, by which the level of the roadway is lowered, and the slopes of the approaches reduced.

OCCUPATION BRIDGE OVER THE RAILWAY AT SUMMERDEN FARM, IN THE TONBRIDGE DIVISION.

Vide Plate 50.

This Bridge is built over a cutting, and the earth was removed without interfering with the portion under the proposed arch, by which the expense of framed centering was saved. There are 33 roods of brickwork in the Bridge.

SPECIFICATION.

The Bridge to be commenced before the upper lift of the cutting arrives at its site.

The ground to be got out to a shape resembling the arch, as shown in longitudinal section, leaving about 2 feet clear space above.

The centering to consist simply of strong arched ribs, which are to be made to the true form required, and should any alteration of slope occur, either by their own weight or otherwise, they are to be adjusted by the wedges beneath them.

The wedges to be of good hard oak or teak, so as to be readily eased or struck when the work is completed, and a sufficient number to be employed in order to give the requisite stability to the ribs.

DETAILS OF TIMBER BRIDGES.

Vide Plate 51.

The abutments and wings at each extremity are constructed of brickwork, but all the rest of the structure is formed of timber.

The span of the arches, formed after the Plan represented, is 32 feet 6 inches, but there are some upon the line of 50 feet.

The details of the Timber Pier, at Folkstone Harbour, are represented in Plate 52, and the construction of the Reservoir, Tanks, &c., at Tonbridge, in Plates 53, 54, and 55. The Turntables on the line of Railway are described in Plate 56.

LONDON AND GREENWICH RAILWAY.

GEORGE LANDMANN, Esq., Engineer.

This short Line is now incorporated with the South-Eastern Railway, of which it forms a branch. The Act of Parliament authorizing the construction of it was obtained in May 1833.

The Railway consists of a double line of rails raised on a brick viaduct, consisting of semicircular brick arches, excepting at the crossings of roads and other thoroughfares, where a suitable mode of construction is adopted. The arches are 18 feet span with piers between them, 3 feet in thickness, and are built of Sittingbourne stock-bricks, and Halling lime-mortar; they are turned one brick and a half in thickness, and in two bricks under the spandrel walls. The viaduct is 22 feet 3 inches in the clear, between the parapets, and tool recesses are carried up in the shape of piers at intervals of every twelve arches.

The rails are laid to the Standard Guage, or 4 feet 8½ inches; the 50 lbs to the yard edge-rails being employed with 18 lbs. chairs, set 3 feet apart, and fixed on granite blocks. A thin piece of elm plank is introduced between the chair and the block; the latter are also bedded in concrete with a layer of sand below. The drain along the superstructure is laid in brickwork in cement.

BRIDGE OVER THE SPA ROAD, BERMONDSEY.

Vide Plates 57 and 58.

Angle of Askew . . . 52° 30′

This Bridge consists of a large centre arch over the roadway, and two side arches over the footways. The imposts on each side of the middle arch are supported by Grecian Doric columns of good proportions. The plinth for the columns, the piers in roadway and the springers to arches, are executed in Bramley Fall stone; the abutments, arches, spandrels, internal spandrel walls, parapets,

&c., being carried up in brickwork. The bricks throughout are good, sound, hard-burnt stocks. The three oblique arches, and solid spandrels over the same, are set in Roman cement, composed of Halling lime and river sand.

The columns supporting the arches are formed of cast iron, and filled up in the interior with concrete. Each column also has a wrought-iron bar passing vertically along its axis, which is let into the plinth at one extremity, and into the stone springers at the other. The latter are connected together by chain-bars secured to a horizontal bar prepared to receive them, and at a level of 4 feet 9 inches above the springing line of the arches.

The chain bars first described are furnished with proper mortices, through which the vertical bars pass.

The spaces between the internal spandrel walls are filled up to the level of the crowns of the arches with concrete, composed of seven parts of river gravel and one of ground Halling lime.

The cornice, parapet, and coping are in Roman cement, and the caps of the recesses on the superstructure are of Bramley Fall stone.

CENTRE ARCH.

	Ft.	Inch.
Perpendicular span	27	9
Span on the face	35	4
Rise	9	0
Radius	22	0
Thickness of rim of arch	1	6

SIDE ARCH.

Perpendicular span	8	0
Span on the face	10	2
Rise	2	7
Radius	6	3
Thickness of rims of arches on the face	1	2
Ditto, in the interior of the work	0	9

DETAILS OF 26 TURNPLATE AT GREENWICH.

Vide Plates 59 and 60.

This Turnplate is sufficiently large to receive both the engine and tender at the same time. It consists of two cast-iron girders, 26 feet in length, placed at a suitable distance apart to receive rails of a corresponding guage to the wheels of the engine. The girders are connected together by strong diagonal bracing, and they are supported on small conical rollers below,—viz., one pair at the extremities, and another pair about midway between the same and the centre pivot on each side; proper bearing plates being laid to receive the rollers. This girder framing is moved by means of a winch fixed to one of the girders, and which turns a pinion communicating with a circular rack.

LEEDS AND SELBY RAILWAY.

JAMES WALKER, Esq., Engineer.

The Act for the formation of this Railway was obtained in May 1830, and it was publicly opened in September, 1834. The line is laid out sufficiently wide to accommodate four sets of rails, although two only are laid down, and the arches of the bridges over it are also built of corresponding width. The rails were originally 35 lbs. to the yard T rails, but 42 lbs. rails were subsequently adopted. They are laid to the 4 feet 8½ inches guage. The gradients are only moderately good, but the curves are generally easy.

Commencing from Leeds, the inclinations are as follows:—

Lengths of Planes. Miles.	Chains.		Ratio of Inclination.			Locations.
	8·00	. . .	level.			
	8·00	. . .	ascending at the rate of	1 in	218	Entrance to tunnel.
	31·80	. . .	ascending „	1 in	349	End of tunnel.
	18·00	. . .	ascending „	1 in	229	
	59·20	. . .	ascending „	1 in	210	
2	4·80	. . .	ascending „	1 in	160	
1	4·20	. . .	ascending „	1 in	168	
2	61·00	. . .	level.			
2	47·00	. . .	descending „	1 in	150	End of New-street cutting.
3	21·00	. . .	descending „	1 in	137	Occupation-road to Milford.
	18·00	. . .	descending „	1 in	182	
6	41·00	. . .	descending „	1 in	3785	Selby station.
20	00·00	. . .				

An assistant engine is employed on the Milford inclines of 1 in 137, and 1 in 150 in the case of heavy trains.

The earthwork is considered to be rather heavy, but is much lessened by means of retaining walls, which are carried along the faces on each side, and thereby cut off or reduce the slopes. Some of the cuttings and embankments are finished in this manner at the feet—i. e., with dwarf walls, 5 or 6 feet high only, and there are some instances where they are carried up the entire height of the embankment, whereby the area of land required is considerably decreased. They are built with a curved batter, the chord line forming an angle of 67½° with the base. Stone fences are requisite on each side at the top, for the security of the passengers, in case the train should get off the rails: the entire width of the embankments at the top is 30 feet; and clear space between the parapets, 27 feet. The greatest depth of cutting is 43 feet; and height of embankment, 50 feet.

The front of Leeds tunnel is represented in Plate 61. This tunnel is 700 yards in length, and the expense of forming it is said to have averaged about £25 per lineal yard. It is carried throughout in 18-inch brickwork, and about two-thirds of its distance is in shale and coal measures, and the remainder in rock. The two shafts used in working it are left for the purposes of ventilation.

Plates 62 and 63 describe the construction of the Depôts at Selby and at Leeds.

The roofing of the Sheds is formed of timber, and it is supported on cast iron columns; the whole having a neat appearance.

MIDLAND COUNTIES RAILWAY.

CHARLES VIGNOLES, Esq., Engineer.

The Act for this Railway was obtained in June, 1836, and the line was opened complete to the public in July, 1840. Thos. Jackson Woodhouse, Esq., was the Resident Engineer appointed to superintend the works.

The line commences at the London and Birmingham Railway, near the town of Rugby; and after passing the large manufacturing towns of Leicester and Loughborough, crosses the river Trent nearly midway between the towns of Nottingham and Derby. Immediately after crossing the river, the line separates and diverges to the eastward and westward; one branch running to and terminating at the town of Nottingham, the other going to the town of Derby, and there connecting with the North Midland Railway, and also with the Derby and Birmingham.

The earthwork is not very heavy; the Leir cutting between Rugby and Leicester being the heaviest, and which is 62 feet deep as a maximum, and contained upwards of 600,000 cubic yards; the slopes are 2 to 1. The Leir embankment also contains 430,000 cubic yards, and is about 40 feet high; also with slopes 2 to 1. Mr. Woodhouse states the average price of earthwork throughout to have been 13*d.* per cubic yard.

The rails are of the parallel form, 77 lbs. per lineal yard, and set in chairs. They are formed in lengths of 15 feet, and have a bearing of 5 feet. The joint chairs weigh 28 lbs., and the others 23½ lbs. The rails are secured to the chairs by wooden keys, according to the plan now generally employed.

Table of gradients of the Midland Counties Railway from Rugby to Derby Junction:—

Lengths of Planes. Miles.	Chains.		Ratio of Inclination.		
	40	. . . .	level.		
5	10	. . . .	descending at the rate of		1 in 330.
2	12	. . . .	descending	,,	1 in 420.
7	30	. . . .	descending	,,	1 in 354.
	18	. . . .	level.		
3	18	. . . .	descending	,,	1 in 387.
	32	. . . .	descending	,,	1 in 704.
	40	. . . .	level		
2	20	. . . .	descending	,,	1 in 495.
1	30	. . . .	level.		
	37	. . . .	descending	,,	1 in 349.
2	56	. . . .	level.		
5	17	. . . .	descending	,,	1 in 504.
	50	. . . .	level.		
1	20	. . . .	ascending	,,	1 in 1333.
1	00	. . . .	level.		
	45	. . . .	ascending	,,	1 in 1120.
	40	. . . .	level.		
2	57	. . . .	descending	,,	1 in 550.
1	01	. . . .	level.		
1	00	. . . .	ascending	,,	1 in 1320.
	53	. . . .	descending	,,	1 in 874.
	14	. . . .	level.		
3	40	. . . .	ascending	,,	1 in 883.
1	02	. . . .	ascending	,,	1 in 541.
	46	. . . .	level.		
2	00	. . . .	ascending	,,	1 in 503.
48	08	to Junction with North Midland Railway at Derby.			

SPECIFICATION

Of the Works necessary in constructing the Viaduct over the Valley of the River Avon, (near its junction with the London and Birmingham Railway.)

Vide Plate 64.

THIS Viaduct consists of eleven Arches, each of 50 feet span, which are to be built agreeably to the plan. The foundations to be sunk to an average depth of 6 feet below the surface of the ground, or to 44 feet below the level of the rails, as shown on the longitudinal section. Should an increased depth appear necessary to the Engineer, or an artificial foundation be required, it will be paid for according to the Schedule of prices.

The structure to be Brickwork, with the exceptions hereafter specified. Every part of the work, where the thickness of the walls will admit of it, to be set flush in grout, and the whole to be put together in the most substantial and compact manner.

The ends of the piers to be faced with the best Staffordshire blue Bricks, properly bonded, and returned 9 inches and 14 inches into the flanks of the piers.

The rings or quoins of the Arches to be similar bricks, and similarly bonded into the soffit; also the Coping of the parapets to be formed of Staffordshire bricks, moulded 14 inches on the bed, and 8 inches thick, rounded on the top, and set 2 inches from the face in Roman cement. The Spandrels and Parapets to be faced with square hard burnt common bricks selected for the purpose, and the clay for the whole of the bricks for this structure to be ground; none other will be allowed to be used. Openings are to be left in the piers of the dimensions shown, with Arches at the top and bottom of the same. Spandrel arches to be built over the piers, and quarters of the main arches, as shown in the sections.

In the centre of each pier, a cast iron Pipe of 2 inches diameter is to be built, to carry off any water which may percolate through the ballast and spandrel arches, and openings to be left in the piers of the spandrel arches, and channels formed, so as to draw any water to the pipe.

The whole of the Arches, when built, to be covered with a clay pun, or Puddle, 9 inches in thickness.

ASHLAR.

Imposts or Caps to the piers to be placed, of the dimensions shown on the enlarged Section, and returned 2 feet 6 inches into the piers. The lower member to be 2 feet on the bed, with 2 inches projection, the upper member to have 12 inches projection, and 2 feet insertion into the wall. A Springer, 10 inches thick at the face, and 2 feet on the bed, to run entirely through the whole of the arches, and upon the face of the same; and to run across the whole width of piers.

The Cornice to be stone, of the dimensions shown on the plan. The upper member to be 15 inches thick, with 15 inches projection; the lower member to be 9 inches high, with 3 inches projection, and both to have at least 1 foot 9 inches bearing on the wall.

The Caps of the piers, at the ends of the parapets, to be of Ashlar, and the whole to be very neatly tooled. The cornice to be in lengths of not less than 3 feet, and the ends closely jointed, and pointed with Roman cement.

The Mortar is to be made by passing the lime and sand through a mill, in the proportion of 1 measure of Lime, newly burnt, to 2 measures of clean sharp Sand, and thoroughly incorporating them together with the least possible quantity of water; and no more is to be mixed or ground than will be used in the work by the expiration of the following day.

All Centering and other materials to be found by the Contractor.

The Earth at the back of the Abutments, and about the wings, to be carried up in courses, and regularly pounded, or rammed to the full height.

The whole of the works to be executed in a workmanlike and substantial manner, to the entire satisfaction of the Engineer.

BRIDGE OVER THE RIVER TRENT.

Vide Plate 65.

The Bridge consists of three cast iron arches, each of 100 feet span, and which are segments of a circle of 130 feet radius, the versed sine of the arch being 10 feet. There are 6 tiers of arches or ribs running throughout the length of the bridge, one under each rail, of which there are two pairs, and one also under each of the parapets. The inner ribs are of greater substance than the outside ones. Each of the ribs is formed of three castings, accurately fitted together, and further joined by diagonal braces, which also connect the whole of them together. These braces were properly prepared, with their faces of contact worked square and parallel by means of a planing machine. The ribs are also further stiffened by other pieces, and they rest on a cast iron abutment plate, thin sheets of lead being laid between the iron and stone, to preserve the latter from the effects of any unequal pressure. The bridge is covered by a timber platform 6 inches thick, upon which oak longitudinal beams are laid to receive the rails.

The Piers of the Bridge are 14 feet thick at the foundations, and diminish upwards to 10 feet; the abutments are 14 feet thick at the foundations, and arched on plan as shown upon the plate. The bridge rests on red marle, intersected with beds of gypsum, and the foundations of the piers were carried up by means of coffer dams. The masonry is seated on a platform of baulks crossed by half baulks, trenailed together.

The total cost of the Bridge was £21,000; the whole of the iron, including carriage and fixing, being £10,000. The amount of cast iron was about 680 tons, and of wrought, five tons.

SPECIFICATION

Of Works required in Constructing a Bridge over the River Trent.

EXCAVATION AND MASONRY.

THE respective parts of the Works are to be built and made of the dimensions shown in the drawings, and agreeably to this specification.

The excavations for the Foundations are to be sunk to the depths shown on the drawing. A Coffer Dam is to be constructed for laying the foundations of the south pier; the dimensions of which, as also the mode of construction, to be approved of by the Engineer.

The dimensions required for the base of the said Pier, is to be enclosed by driving Sheeting Piles, 6 feet in length and 4 inches in thickness, each having a wrought iron shoe of $1\frac{1}{2}$lbs. on its lower end, the piles to be driven until their tops are nearly level with the river bed. The space so enclosed is then to be excavated from 3 feet 6 to 4 feet below the bed of the river, and layers of Concrete, forming a depth of 2 feet, to be laid completely over and upon the space within the sheeting piles, the upper layer of concrete having been truly levelled up and down stream, a Grating of Timber to receive the masonry is to be laid upon it.

The component parts of the concrete, and the proportions of each, will be hereinafter specified; and the foundations will be required to be kept free from water, until the concrete has become properly set.

The Grating to be of Memel Beech, or Elm timber, of the following dimensions: the outer Sills lying transversely to the bridge, to be 12 inches square; the intermediate ones, 3 in number, to be 12 by 9 inches: the Cross sills to be 9 inches square, and to be sunk into the transverse ones at the points of intersection, then to be properly trenailed and secured: the Spaces between the timbers to be filled with Concrete.

A similar grating, &c., to be used for the other piers and abutments, if thought necessary: in that case they will be paid for according to the Schedule prices.

The whole of the Abutments and Piers are to be built of Ashlar stone, the largest blocks being selected for the bottom courses, and no course to be less than 18 inches high; the beds of the stretchers to average 21 inches, the headers to form a third of the whole face, and to be 3 feet 6 inches deep on the bed, the beds and end joints to be truly wrought. The face from the foundations, to 2 feet below water level, to be pick dressed. The remaining part to have a tooled or drafted margin, the remainder of the face to be neatly punched.

The filling of the Piers and backing of the Abutments to be of Ashlar stone, having one good bed.. Two stones may be used to make the height of a course, each of which must be evenly levelled off: sound well burnt Bricks may be substituted for the stone backing of the abutments, if the Engineer should approve of the quality.

The impost or moulded course under the springing of the Arches to be neatly tooled, and wrought in lengths not less than 3 feet, to be 2 feet on the pier, and filled with solid Ashlar masonry between.

The salient Angles of the piers to be formed with stone blocks of large dimensions, and no joint to be within 2 feet of the angular point.

The Caps of the Piers are to be formed in two blocks neatly tooled, close jointed and connected with iron dowels.

The stone blocks forming the Springing courses to be the whole depth of the cast iron abutting or Springing Plates which is laid upon them, the bottom beds to be 3 feet deep, and not less than 3 feet long; the back joints to be wrought square, and filled in with square wrought Ashlar masonry, so as to make the top of the piers a close bed of Ashlar work. The backs of the Springing Courses and the filling course are to be jointed and joggled thus  into which the springing plates, junction frames, or pier standards, are to be sunk.

The wings are to be faced with Ashlar stone, neatly tooled; and the backing is to consist of flat bedded Rubble masonry, properly bonded, and closed in each course, the Ashlar work to average 1 foot 9 inches in the bed, and to have headers in the proportion before described for the piers and abutments.

The Base Cornice (the members of the latter are to correspond with the cast iron cornice over the arches) and Coping to be of Ashlar stone, of the figure and dimensions shown on the drawing, closely tooled. The Parapet is to be of solid blocks, each the height of the Parapet, margin drafted and punched, as before described, and to be coped with a moulded coping of 12 inches thick, having 4 inches projection on the outer face.

The whole of the Stone for this work to be of the best quality, from the

Cromford quarries, or some other which produces equally good stone; as to colour and quality, to be approved of by the Engineer.

The exterior face of all the Masonry in the Bridge, to the level of the tops of the piers from the foundations, for 9 inches in depth, from the outside, to be set in the best Roman cement, with a proper proportion of clean sand, or in mortar, made in the following manner:—" Two measures of barrow Lime, one measure of Pozzuolana, and three measures of clean Sand; the whole to be well ground and tempered until it forms a tough paste. No more water is to be used in mixing than is absolutely necessary to thoroughly incorporate the mixture. The Backing Mortar to be composed of one measure of Lime, half a measure of Pozzuolana, and two measures and a half of clean sharp Sand, ground, tempered and mixed as before stated.

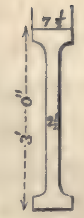
The Concrete is to be made of fresh barrow Lime, ground as described for the mortar, and mixed with clean sandy Gravel, in the proportion of 1 of lime to 4 of gravel, mixed with the least possible quantity of water; the whole to be well beaten, and turned twice at least with a shovel, and used while in a hot state.

The Contractor is to cut away and open the banks of the River, to suit the new constructions, as may be directed. He must also cut a temporary Channel for the water on the north side, to enable him the better to get in the foundations; and also construct all Dams necessary for the construction of the work. He must find all materials necessary for the construction of the work, according to the plan and this specification, and complete the same to the entire satisfaction of the Engineer, who shall have power to reject any improper materials, or order any insufficient work to be taken down and rebuilt; and his decision as to the intent and meaning of any and every part of this specification is to be binding on all parties concerned.

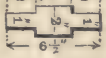
IRON WORK.

The Bridge is to have 3 Arches, each of 100 feet span, having a versed sine or rise of 10 feet; the inner curve being a segment of a circle of 260 feet diameter.

Each Arch is to consist of six Ribs of cast iron, and each rib to be composed of 3 pieces; each piece being a solid casting, forming the segment spandrels and roadway bearer. The Segment Pieces are to be 3 feet deep at the springing, and to diminish 2 feet 6 inches at the crown; the plate of the segments, excepting the outer ones to be 2½ inches thick, strengthened with a top and bottom web, or

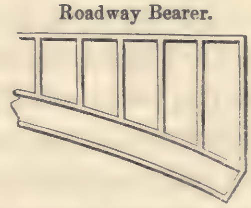


Flange, $2\frac{1}{2}$ inches square, thus the plate of the two outer segments to be 2 inches in thickness. The joints of the segments are to be connected by Tie Plates of a similar depth and thickness, and reaching the entire width or breadth of the bridge. The webs or Flanches to be returned on the ends of the joints of the segments, by which they are to be secured to the Tie plates with $1\frac{1}{2}$ inch screw bolts.

And further, to be braced laterally with feathered Diagonal Braces between each tie plate, secured to the segments by inch screw bolts, passing through flanches to be cast upon them; the Braces to be 6 inches broad in section, thus . The ends of the Segments are to rest upon and be fitted to cast iron  Springing Plates, bedded and sunk into the abutments and piers, 3 inches thick, with raised grooves to receive the same. The plate of the Roadway Bearers is to be $1\frac{1}{2}$ inch thick and 9 inches deep, with a flanche on each side, on the top, of 3 inches by $1\frac{1}{2}$.

The Spandrel fillings, next the pier standards, are to be 6 by 4 inches, and reduced gradually to 4 inches square, as they approach the crown of the arch; those on the outer ribs to be formed in section, thus  with Gothic heads, as shown in elevation.

Roadway Bearer.



The inner four to have plain vertical pieces of the above dimensions, and the Gothic heads to be omitted, thus. The several spaces of same being the same width as the outer ones.

The pier Standards are to be of the dimensions shown on the elevation, and 2 inches thick; those on the outside to have a sunk panel, the inner ones plain; and they are to be secured at their junction with the ribs by flanches, with proper screws, bolts, and nuts.

The Roadway bearers are to be braced by one set of Diagonal Braces, between the crown of the arch and pier standards, to act on points at least 12 feet apart in the length of the bearer; to be feathered castings, 4 by 2 inches—thus  attached to the bearers by flanches, bolts, &c., as before stated.

A Cornice of cast iron, 3-4ths of an inch thick, and of the figure shown on the elevation, is to be secured to the outer bearers by inch screw bolts.

The parapet railing is to be of wrought iron, 7-8ths of an inch square; but the Gothic heads may be of cast iron. The handrails to be $2\frac{1}{2}$ inches broad, and 7-8ths thick, rounded on the top, and riveted to the Gothic tops of the railing. The number of them is shown on the drawing, and they must be keyed into the base or plinth of the parapet.

The Roadway is to be formed of half baulks of Memel timber, Kyanized. To be not less than 12 inches broad and 6 inches thick, and placed so as to leave spaces of 2 inches between them.

Each Timber to reach the entire width of the bridge—namely, 27 feet; and to be secured to the roadway bearer in two points of its length, by screw bolts $\frac{3}{4}$ths of an inch square—the bolts to be dipped into white lead before being driven; or, if the Engineer shall direct, the screw bolts shall be dispensed with, and the timber secured to the bearers by battens spiked to them from below; in which case, the upper flanche of the bearer will require to be cast beveled, so as to form a dovetail between the battens.

All the Joints of the Castings shall be truly fitted solid, by chipping or filing, and no packing of sheet iron, wedges, or cement, shall be used, but the workmanship shall be of the very best kind possible. The Castings shall be of the best grey metal, No. 2, without flaw or defect, and shall be put together and erected at the foundry where they are cast, and be subject to the inspection of the Company's Engineer, who shall reject all such as he may deem insufficient.

The Contractor to find all Models, fitting materials, centres, timber, tackle, and labour; to make, erect, and complete the iron work as aforesaid upon the masonry provided to receive it, according to the true intent and meaning of the Plans, sections, and specification, and to the entire satisfaction of the Engineer.

The iron work to be painted when temporarily erected, and two coats when permanently fixed, of the best white lead and linseed oil.

SLAMANNAN RAILWAY.

JOHN MACNEILL, Esq., Engineer.

Slamannan is a village in Scotland, and situated in the upper part of the county of Stirling, or about fifteen miles in a direct line from Glasgow in a north-easterly direction. This Railway forms one of the links of communication between the mineral districts of Stirling and Lanarkshire, and the cities of Edinburgh and Glasgow. The Act for the undertaking was obtained in the year 1834, and the line was opened in the spring of 1840.

The line of Railway is 12.488 miles in length, and has both severe gradients and sharp curves upon it. There is an incline of 6,635 yards, 1 in 100, and another 3,435 yards at the same rate, amongst others, and which are worked by locomotives. The curves vary from 20 to 80 chains radius.

The line is executed on a scale of rigid economy, and the earthworks are not heavy. Only a single way is laid down, and it is estimated to have cost about £8,128 per mile, the permanent way included, which was executed for 5*s.* per lineal yard. The completing of the way with a double line is estimated at £10,000 per mile.

SPECIFICATION

Of the Work to be executed by the Contractor for the First and Second Lot of this Railway.

This portion of the Railway commences at a point on the Ballochney Railway, in the lands of Stanrigg, marked by a pin driven into the ground, and numbered 1.

This point corresponds with the points marked A on the Plan and Section of the first division of the proposed Railway hereto annexed.

The Line runs in nearly a N. E. direction through the lands of Longrigend, Longrig, Lodge, Binnyhill, Balquharson, and Peatrigend, and terminates at the fence at the east side of the road leading to Pirney Lodge, after crossing the Burn.

The Red line on the plan represents the centre midway between the two lines of Railway, and is now marked out by stakes driven in the ground at every 100 feet apart, which are numbered on the top, commencing with the figure 1, at the Ballochney Railway. These numbers are continued in regular series up to No. , which terminates the first Lot.

The stakes are represented on the section by the same figures. The height of embankments, and depth of cuttings, are shown by the figures in red on the Section at each of these stakes, which are 100 feet apart along the whole line.

Two large stakes will be driven firmly into the ground; one near the middle of the lot, the other near the termination, in the lands of Peatrigend, but out of the line of Railway, so as not to be disturbed by the operation of the works; and which are to serve as standard Bench marks, to which the level of the stakes are to be referred in the first instance, and during the progress of the works.

These Bench marks and stakes will be levelled by the Superintendent, and the Contractor is to satisfy himself of their accuracy before he commences the work; and he is to sign a paper to that effect, to prevent all disputes as to levels, as no extra sum whatever will be allowed the Contractor for cutting or embanking, beyond the depths or heights marked on the section hereunto annexed, in order to acquire the rates of Acclivity marked on the said Section; that is to say—

1 in 112 from A to B, being a distance of $1733\frac{1}{3}$ yards;
1 in 349 from B to C, being a distance of $1233\frac{1}{3}$ yards;
1 in 300 from C to D, being a distance of 400 yards;
1 in 100 from D to E, being a distance of $6649\frac{2}{3}$ yards;

the whole measured along the surface of the Rails, when laid in the chairs, and fixed to the blocks or sleepers.

CUTTINGS AND EMBANKMENTS.

The roadway through the Cuttings, at the surface of the rails, is to be 25 feet wide, except through the Moss, where it is to be 35 feet wide. The sides of the Cuttings are to be formed with slopes, 1 to 1, where the cutting does not exceed 4 feet in perpendicular height; $1\frac{1}{2}$ horizontal to 1 perpendicular, where the height does not exceed 10 feet; and at all heights above that, the slopes are to be 2 horizontal to 1 perpendicular.

The Embankments are to be 30 feet wide, when raised to the proper height, and formed ready to receive the ballasting, except in Moss, where it is to be 35 feet. The slopes of all Embankments are to be 2 horizontal to 1 perpendicular.

All the Materials arising from the cuttings are to be employed in raising the embankments; and should it produce more than is necessary for this purpose, the residue is to be applied to giving a greater width to the embankments, by widening out the slopes, or otherwise disposed of in places equally convenient for the Contractor, as may be pointed out by the Engineer or Superintendent to the Company for the time being. But if the materials procured from the cuttings be not sufficient to make up the embankments to the specified heights and widths, a sufficient quantity must be procured by making the cuttings wider than specified, or by flattening the slopes, as may be pointed out by the Superintendent or Engineer, without any additional expense to the Company.

Before any Embankment is commenced on any part of the line, except through the moss, the Soil is to be raised for a depth of 6 inches over the whole space to be occupied by the embankment, and for the depth of 1 foot over the space to be excavated, and removed to some convenient site, pointed out by the Inspector or Superintendent; to be hereafter employed in soiling down the slopes of the Cuttings to a depth of not less than 6 inches, and the slopes of the Embankments to a depth of not less than 12 inches. This part of the work is not to be done until after all the slopes are carefully levelled, trimmed, and dressed, and reported by the Superintendent to be sufficiently consolidated and firm.

The Embankments are to be raised by Lifts not more than 4 feet thick, and the Contractor is to satisfy himself that each layer is perfectly consolidated before he commences a new one over it.

In the cuttings through the Moss, Drains are to be formed at the bottoms of the slopes, as shown in the Drawings hereunto annexed (vide Fig. 1 on Plan.) These drains are to be 9 feet wide at top, 3 feet deep; to slope on the outside as the cuttings—that is, 2 horizontal to 1 perpendicular, and on the inside 1 to 1. Two Drains are also to be cut, one on each side of the road, at the top of the cutting, and 6 feet from the edge of the slopes; these Drains are to be 8 feet wide at top, 3 feet at bottom, and 3 feet deep: the moss taken from them to be deposited on the outside of the drains, not less than 3 feet from the edge thereof.

In the moss the embankments are to be formed with slopes of 2 horizontal to 1 perpendicular, and to be 30 feet wide at the surface level of the rails.

Before the Sleepers are laid on the surface of the embankment, a space of 15 feet in width is to be covered with heather and green sward, or divits under the ballasting.

Should Rock be found in the cuttings, the slopes may be ½ horizontal to 1 perpendicular; and the Contractor is to allow the Company, or the Contractors for the other portions of the line, to quarry and take away whatever quantity they may require for Blocks, masonry, ballasting, or any other work the stone may be fit for, without any charge whatever, provided there is a superabundance above what he will require for his own portion of the work; the Company, or Contractors, giving him, in place of the stone thus taken away, as much earth or other material as will make up the same quantity of embankment, should he so require it.

DWARF WALLS.

Vide Fig. 2 on Plan.

The Contractor is to cast out the foundations, and build Dwarf Walls throughout the cuttings, except in moss, to the extent of 2,700 yards, on each side of the road; these Walls to be 21 inches thick at bottom, 15 inches at top, and 2½ feet high, and coped with two courses of 3 inch divits; these dwarf dykes to be of substantial dry stone work, with thorough bonds not more than 1 yard apart.

FENCES.

Post and Rail Fences are to be erected along each side of the Railway, at the top of the cuttings, and at the bottom of the embankments, except through moss;—these Fences are to consist of the best description of post and rails, and

quick plants, or of earthen mounds, and stub fence. These mounds to be 2½ feet high, 5 feet broad at the bottom, and 3 feet broad at the top; the sides, to the thickness of 1 foot, to be laid with divits on their flat bed, and the centre to be made up with fine soil, taken from the Railway sides of the Fences. The plants are to be provided by the Company, but they are to be planted by the Contractor in a careful and workmanlike manner, at such times and seasons as may be pointed out by the Engineer to the Company. The Contractor to have the liberty of putting up either the *post and rail* fence, or *mound and stub* fence, as he may think proper, but it is to be uniform throughout the whole length.

DRAINAGE.

Besides the preparatory Drains already described along the moss, Cross Drains are to be formed where there is any run of water, or means of carrying off surface water. These Drains are to be open cut, 4 feet wide, and 3 deep, and made to communicate with the nearest stream or outlet for the discharge of the water.

Two Main Drains are to be cut, in such places as may be pointed out by the Engineer; these drains to be 10 feet wide at top, 3 feet wide at bottom, and of sufficient depth to communicate with the side drains already described in the cuttings through the moss. These drains are intended to carry off the water that would otherwise accumulate in the side drains, and overflow the road. They must be made in the best manner for discharging the water, and carried to a sufficient length to communicate with the stream that now runs to the South of the moss, or to some low situation where the drainage may be affected.

The Contractor shall also open the Foundations and build Drains along the Railway, (except in moss,) and embankments to the extent of 2,700 yards; the bottom of the drain to be 1 foot below the bottom of the level prepared for ballasting. The bottom of these drains are to have the same declivities as the Railway when finished. These drains are to have Inlets in such places as may be pointed out by the Engineer. The Contractor is also to open foundations and build Cross Drains to the extent of 350 yards, on such parts of this portion of the Railway as may be fixed on by the Engineer, or his Inspector.

All these Drains shall be 1 foot square in the clear; the Side Walls shall be substantial Rubble masonry, not less than 1 foot thick, and laid in well prepared mortar; the Covers not less than 4 inches thick, no stone of which shall be less than 12 inches broad, and neatly hammer-dressed in the joints, and to have a bearing on each side of not less than 6 inches; the Bottom to be laid with stone, set on edge, not less than 5 inches deep, and laid in well wrought clay puddle.

440 yards of Open Drain is to be made along the outside of the Railway, in Mr. Waddell's lands of Peatrigend. Besides the 350 yards of cross drains already described, five Cross Drains are to be built in the lands of Balquharson, the property of Mr. Waddell.

Three wooden Trunks, 18 inches square, are to be provided, and of sufficient length to cross the Railway in the moss, (vide Fig. 4 on Plan,) and are to be laid sufficiently low to carry the water from the main drains on the upper side of the moss to the main cross drains before described. These Trunks to be of Elm, or Fir, 3 inches thick, spiked, and bound with oak ties, or bonds, 4 inches square, tenanted and keyed; these bonds to be placed 4 feet apart along the trunks, and one 6 inches from each end. Should more of these trunks be necessary than those mentioned, the Contractor to be allowed for them extra, at a fair price, to be settled previous to the work being done.

BALLASTING.

The whole extent of this division of the Railway is to be ballasted to the depth of not less than 9 inches on the Embankments, and ten inches through the Cuttings, the width to be 12½ feet. The remaining portion of the width of Railway to remain at present without ballast, for a space of 200 yards in length. The ballasting is to be the full width of 25 feet, for the Sidings in such places as may be hereafter agreed on by the Engineer.

The Ballasting is to be of hard durable free stone, from the quarry at Arden, or any other quarry that may be approved of by the Inspector, broken so that every stone may pass in any direction through a ring 3 inches diameter. This ballasting is to be procured, carried, and spread on the Railway by the Contractor; but not until the Engineer is satisfied that the embankments are consolidated, and the surface prepared and levelled, and brought to the rates of Acclivity that will be necessary to produce the rates already specified, and marked on the section, when the rails are laid.

Before the Ballasting is laid through the Moss, the surface is to be first covered with a layer of goss, whin, or fern, over which a layer of green vegetable sod or turf is to be laid, 4 inches thick, evenly laid and jointed: if Gravel can be had, it may be used over the moss, instead of broken free stone; but it must be put on double the thickness above specified—that is, 20 inches thick. The ballasting may be got at Callough Burn quarry, or such other quarry as may be approved of by the Resident Engineer.

BLOCKS AND SLEEPERS.

The Blocks to be provided for this work are to be taken from Craig Mochan, or Avon Bridge, or such quarries as may be approved of by the Inspector. To be not less than 9 inches thick, 18 inches square on the top, and 20 inches on the sole; those at the joinings to be 12 inches thick, 20 inches square on the top, and 24 inches on the sole. To be free from cracks or fissures, and otherwise neatly hammer-dressed to the shape of the drawing, with the top and bottom quite parallel, and so that every block shall rest on the natural bed of the stone. Two holes are to be bored in each block, 5 inches deep, and $1\frac{1}{2}$ inch in diameter. These blocks to be placed as hereafter described, through the cuttings and embankments on the solid ground.

Through the moss, Sleepers are to be used; they are to be of fir, or elm, that would square to 8 inches, and to be 9 feet long. Longitudinal Beams are to be laid along the sleepers, at least 9 feet 9 long, and 4 inches deep, and 10 inches broad, scarf jointed, to receive the chairs for the rails; the spikes to pass through these longitudinal pieces, and enter at least 3 inches into the sleepers.

The Blocks and Sleepers to be placed 3 feet apart, for receiving the chairs.

In the very soft and deep portions of the moss, and such places as the Resident Engineer shall direct, there must be a Platform of Timber, about 100 yards in length, (vide Fig. 6 on Plan:) this platform is to consist of common Fir poles, 5 or 6 inches diameter, and 10 feet long, placed side by side, so as to fill up the space between the sleepers; two beams of timber, 8 × 10 inches, are to be laid along the sleepers in the line of the rails; these beams are to be laid so as to break joint with the one on the opposite side, and to be firmly fixed to the main sleepers by brackets and bolts, the joining of these beams to be at a main sleeper, the openings between the sleepers and the cross pieces to be filled with moss, or heather, and the whole covered with gravel, or quarry chips, 4 inches thick. As the length of Platform that will be required is uncertain, the Contractor is to give in his tender a price per running yards. Should it be required, upright fir piles are to be driven into the moss, for the sleepers to rest upon; these piles to be 8 inches diameter, and 8 or 10 feet long; the sleepers to be firmly spiked to the piles, and their ends secured by diagonal braces. This work is to be estimated for by the yard, so that it may or may not be used, as occasion requires.

RAILS.

The Rails required for the work will be provided by the Company; but the Contractor is to load, and lay them through the whole extent of this division of the Railway, in a single road, and that in the centre of the formation, with one set of offset plates, blocks, and other materials, and works necessary for the connexions. All the Blocks, sleepers, offset plates, and rails, are to be accurately laid, both as to the line of direction, curve, and level. The joint Chairs to be neatly keyed, and the intermediate bearing Chairs carefully wedged.

The iron of which these keys and wedges are to be made, will also be provided by the Company, but the Contractor for the work must execute the workmanship thereof, and carry them to the line.

The Chairs are to be fixed to the blocks by two pegs, made of Scotch oak, with an iron pin, $\frac{3}{4}$ of an inch diameter, and 6 inches long, in the centre of each. The Company to provide these pins, but the Contractor is to provide the pegs.

Before laying the Blocks and Sleepers, the ballasting under them, and immediately adjoining them, is to be reduced to a solid and compact mass, by ramming them with a paviour's jumper, except where the sleepers are laid on moss.

The Rails will be delivered to the Contractor at the nearest point of the Ballochney Railway, and the Chairs, and other castings, from the foundry, in , at such times, and in such quantities, as the Resident Engineer may think desirable or necessary.

The Contractor is to be allowed the use of part of the Rails and Chairs, for carrying out the stuff, or loading building and other materials along the line; but he must provide Sleepers, offset plates, switches, keys, and pegs, necessary for laying the temporary roads.

The Contractor shall furnish and provide all the necessary Tools and apparatus for laying the Blocks, sleepers, chairs, and rails, and adjusting them to the proper curve and level.

The Contractor not to be allowed the use of more than three quarters of the quantity of Rails necessary for the permanent road; and should he injure, break, lose, or destroy, any of the rails or chairs, in using them for the Company's road, he must replace the same with others in every respect similar to those he may have injured, broken, lost, or destroyed.

In order to provide for the safety of the rails, the Temporary Road is to be laid, and maintained in good condition; and the waggon wheels and axles employed thereon shall also be properly constructed, and kept in good working order, to the entire satisfaction of the Engineer to the Company for the time being; and no Waggon weighing more than $2\frac{1}{2}$ tons gross, shall upon any account be allowed to pass along any of the temporary roads.

BOXING, &c.

When the Rails are laid, and permanently fixed, to the satisfaction of the Engineer, the ballasting is to be covered with good Boxing material, 10 inches thick in the middle between the rails, and diminishing gradually to 5 inches at the sides, as represented in the cross section, (see Figs. 7 and 8 on Plan.) The Boxing to consist of hard, durable free stone, broken so that no stone will weigh more than 4 ounces. That part between the rails, for a width of $3\frac{1}{2}$ feet, and depth of 6 inches, is to be laid with the hardest of the stone produced from the dressing of the blocks, or scaling of free stone; these to be broken, so that no stone will weigh more than four ounces. The surface to be blinded, or dressed with 2 inches of fine gravel, or quarry chips, free from clay, to within an inch of the surface of the rails. If required, one side of the road through the cuttings, to the extent of 2,700 yards, is to be edged or bordered with a neatly hammer-dressed free stone Curb, no stone of which is to be less than 14 inches deep, nor less than 15 inches long; to be 5 inches thick at top, and 8 inches at the bottom, and to be neatly dressed in the joints to the depth of not less than 6 inches. The water channels, to the breadth of 6 inches, and to the same extent as the curb stone above described, is to be laid with hard stones set on edge, not less than 4 inches deep, and all laid and neatly packed, pinned, and pointed. The boxing to be taken from Avon Bridge or Craig Mochan quarry, or such other quarry as the Resident Engineer may approve.

When the boxing and roadway is completed, the surface is to be neatly trimmed and dressed, exactly to the curve represented on the cross section.

MASONRY.

There are to be three Occupation Bridges, two Parish road Bridges and four Arches, or culverts, in this division of the work; the particulars of which are as follows:—

No. 1. Parish Road and Bridge.

The Parish Road, leading from Avonhead to Slamannan, is to be crossed by the Railway at the point D, as shown in the plan, in a 9 feet cutting. By lowering the parish road, a crossing may be made on the level, and in this case a bridge need not be built; but should the Company not be able to effect such an arrangement, then the Contractor is to build a bridge as shown in Plan No. 1, and according to the following specification:—

The foundations are to be excavated sufficiently deep to secure a solid and uniform bearing. The walls of the bridge to be founded, and carried up to 1 foot above the surface of the ground, with stones measuring not less than 6 inches thick, nor less than 6 superficial feet on the bed; the joints to be made to fit each other, and laid in even courses of uniform height.

The face of the Abutments, arch, wings, parapet, and outside spandrel walls, to be coursed work, with close square joints. No course in the abutments shall be less than 8 inches thick, and to be of the same thickness throughout; no stone in the abutments to be less than 1 foot 4 inches on the bed; no stretcher less than 18 inches long, and no header less than $2\frac{1}{2}$ feet long, laid 1 header for every 2 stretchers. None of the arch stones to be less than 21 inches long, nor less than 11 inches deep, and their beds neatly dressed, to radiate to that part of the arch where laid.

The face of the Abutments, arch, corners of wing walls, and spandrel walls, likewise to have chisel draft round each joint, and bratched in the centre, not less than twenty-four stripes to the foot.

The quoins of the Abutments, ring pins, string course, and coping of parapet, and pillars at the ends of parapet, to be droved work; the quoins and ring pins to project $\frac{3}{4}$ of an inch, and each joint to be chamfered to that depth, and the ring pin to be made to vary in depth, so as to square with the joints of the outside spandrel walls. No course in the wing walls to be less than 8 inches thick; no stone less than 12 inches broad on the bed; no stretcher less than 8 inches long; no header less than 24 inches long, laid 1 header for every 2 stretchers.

The face of the Wing Walls is to be neatly hammer-dressed, with a chisel draft round each joint. The string course to be 12 inches thick, and no stone to be less than 18 inches long, and to project $2\frac{1}{2}$ inches. The parapet wall to be 1 foot thick, and 1 stone in breadth, wrought in the same manner as the abutments, and spandrel walls. The cope of the parapet walls to be 16 inches broad, and 9 inches thick at the centre, and weathered off $2\frac{1}{2}$ inches on each side; no stone to be less than 18 inches, and to be connected to each other by cast iron dowels, 6 inches long, and $1\frac{1}{2}$ inch square, run with cement.

The cope of the pillars, at the extremity of the parapet walls, to be 1 foot thick, dressed, and weathered off, as described for the cope of the parapets, and firmly bolted to the masonry below.

The other parts of the building not here described, to consist of substantial Rubble masonry; and all the stones to be laid on their natural bed, and all well packed, primed, and pointed.

The back of the Abutments, and space behind the wing walls, to be made up with hard dry materials, in courses not more than $1\frac{1}{2}$ foot thick, and beat up hard, and firmly placed behind the walls.

When the Masonry is completed, and finally approved of by the Engineer, then the approaches and roadway are to be made up by the Contractor, and the roadway is to be covered with broken stones to the breadth of 12 feet, and 1 foot thick.

The Contractor must be particular as to making up the Mortar fresh before it is used; it is to be composed of good lime, and mixed with sharp river sand, in the proportion of 1 of Lime to 2 of Sand. The lime to be well burned and slacked, and the whole well wrought, and thoroughly mixed with the sand, and used whilst fresh.

The Contractor is to make and maintain a Temporary Road, for the accommodation of the public, while the bridge is erecting; he is to fence off the same, and do everything else that the Inspector may deem necessary for the safety of the public.

As it is uncertain whether this Bridge will be required or not, or the parish road changed, the Contractor is to specify the sum for which he will build it separately.

No. 2. Occupation Bridge.

Vide Plate No. 67.

The Contractor is also to excavate the foundations, and build an Occupation Bridge over the Railway, in the lands of Longrigend, at the point marked E in the plan and section. The Bridge is for the accommodation of the occupier of the land, and is to be built according to the Plan No. 2, the Abutments and Wing Walls according to the specification for the Bridge No. 1.

Timber Beams are to be thrown across the piers, instead of a stone arch, as shown in the plan and sections. These Beams are to be of Memel Timber, 1 foot square, and trussed with 2 inch round iron, resting in three Saddles, as shown in the plan. The Beams are to rest on a sleeper of Memel, 6 inches by 12, and are to be bound and connected by an iron Rod, and the upper surface sheeted with planking of the best description, 3 inches thick, firmly spiked to the main beams, and the roadway protected by two iron hand rails, as shown in the plan.

No. 3.—An Arch is to be built under the embankment, at the point marked F in the plan and section, for farm occupation. This Arch is to be built according to the Plan No. 3, which accompanies this specification. The ground is to be Excavated to a sufficient depth to secure a good and solid base for the masonry. The whole of the walls are to be founded with stones, not less than 2 feet broad, 4 feet long, nor less than 10 inches thick, and dressed to a parallel upper and under bed; hammer-dressed in the joints, and carried up in this manner to 1 foot above the level surface of the ground.

The Abutments, arch, and wing walls, shall be of coursed work, and of the same thickness throughout. No course in the abutments, or wing walls, to be less than 10 inches thick, and no stone to be less than 15 inches broad on the bed; no stretcher to be less than 2 feet long, and no header less than 3 feet long, and laid header and stretcher alternately. No arch stone to be less than 1 foot 9 inches long, nor 2 feet deep at the spring, but may be diminished gradually to 1 foot 9 inches at the crown, and no course to be less than 9 inches thick. The soffit of the arch is to be neatly dressed to the curve, with a chisel draft round each joint, and neatly picked between, and all the joints to be dressed full and fair. The quoins of abutments to be returned with stones, not less than 18 inches broad, and 3 feet long, alternately, and those with the ring pin to be droved work.

The Wing Walls are to be coped with stones, set on edge, 1 foot deep, and 1 foot 9 inches broad, with a 3 inch projection; to have a chisel draft on each joint, and left rough in the centre.

All the work in this Bridge, or Arch, not particularly specified, is to consist of the best and most substantial rubble masonry, and the large flat bedded stones laid so as to require little packing. The mortar used to be similar to that already described, and the whole to be executed in a substantial and workmanlike manner. The whole of the arch is to be covered with a layer of well wrought clay Puddle, not less than 18 inches thick.

In putting in the embankment near the arches, and other masonry, care must be taken to lay the stuff in regular courses, not exceeding 2 feet thick; which is to be pounded well up to the masonry, and beat into a solid, firm mass, for a distance of 15 feet at least from the face of the work.

No. 4.—An Occupation Bridge is to be built in the lands of Binney Hill, at the point marked G in the plan and section, in 30 feet cutting, according to the plan marked No. 4, and the specification for the Bridge No. 2, of the same description—that is, Stone abutments, and wing walls, and Timber roadway.

No. 5.—A Bridge for the parish road to Slamannan, by Binney Hill, at the point marked H, in 21 feet embanking, according to the Plan No. 5, and agreeable to the specification for the Bridge No. 1, already described.

A 9 feet arch is to be built over Collagh Burn, at the point marked 1 on the section, according to the Plan No. 6, on the occupation road to Binney Hill, the property of Mr. Waddell, and conformable to the specification of the arch over the said Burn, in 35 feet embankment, as hereafter described.

The accommodation Road to Binney Hill is to be raised, as shown in the ground section at I, so as to pass over the arch. It is to be 12 feet wide, and to be covered with 6 inches thick of stone from the Collagh Burn quarry, properly broken, and laid on at such times, and in such quantities, as may be pointed out by the Inspectors.

A Fence is to be erected on each side; it is to be of dry stone, or post and rails, as may be most agreeable to Mr. Waddell. A Retaining Wall may be found necessary on the East side of this road; if so, the dimensions and price is to be fixed by the Inspector, and the amount allowed in addition to the Contractor.

In case the Company should deem it advisable to deviate or alter any of these plans of Bridges, and build others of a different description, or omit them altogether, then the Contractor is to be furnished with another plan and specification, to enable him to make a tender for such work: or the Company may have the power of letting these Bridges to other Contractors, should they think proper to do so; in which case, the estimated sum for these Bridges is to be deducted from the amount of the general estimate, a detail of which is to be annexed to the Contract.

ARCHES, OR CULVERTS.

Besides the bridges above specified, a Culvert, 4 feet wide, is to be built in the lands of Lodge, under a 17 feet embankment, according to the figures 4, 5, and 6, on the Plan No. 7.

The masonry in the Abutments and Wings to be of sound Rubble, the stones to be laid on their natural beds, and all well packed, primed, and pointed; the masonry of the Arch to be of dressed stone, neatly jointed and dressed, and finished in a workmanlike and substantial manner. The back of the abutments, and space behind the wing walls, to be made up with hard dry materials, in courses not more than 18 inches thick, beat up hard, and firmly placed behind the walls. The bottom of the Culverts to be paved with hard stone, firmly laid, and packed with stone chips, and the ends secured by a row of large stones.

A Second Culvert of the same width is to be built in the same lands, according to the figures 1, 2, and 3, on Plan No. 7, and of the same description of masonry as already described for the first culvert.

An Arch, 9 feet span, is to be built over the Collagh Burn, under a 35 feet embankment, according to the figures 1, 2, and 3, on Plan No. 8. The ground is to be opened for the Foundation in the direction of the stream; it is to be sunk 6 feet below the ground line, or as much more as may be necessary to secure a sure and firm bottom. The foundations of the Abutments and Wings to be of sound rubble masonry ; feet thick at the base, to have an off of at height, and 9 feet thick within feet of the ground line. The Abutments to be of sound rubble, hammer-dressed on the face, and no course to be less than 8 inches thick, and to be of the same thickness throughout. None of the arch stones to be less than 18 inches long, nor less than 12 inches deep, and their beds neatly dressed to radiate to the arch. The Arch to be 9 feet span, to rise 3 feet, and to spring feet above the ground line. The to be hard sound stone, 9 inches deep, laid dry, and firmly packed. The Wing Walls to be feet long, to be founded as low as the abutments, if found necessary, and to be built of sound stone masonry, feet thick, and at the ground line. The Spandrel and Wing Walls, from the level of the ground line, to be thick, the counterforts to rise to the level of the springing. The parapet and wing walls to be coped with stone, similar to the bridges already described.

BREAST WALL.

A breast or Retaining Wall is to be built along the bottom of the slope, in front of Binney Hill Lodge, to prevent the slopes from being injured by a run of water in Collagh Burn in the times of flood. It is to be 2 feet 6 at bottom, 14 inches at top, 4 feet high, and 300 feet long, or more if required; the running yard should therefore be stated.

An Arch is to be built over the Cross Burn, in a 14 feet embankment, extending under the road to Slamannan by Pirney Lodge. It is to be 7 feet span, to be built according to the 4, 5, 6, in Plan No. 8, and agreeable to the specification of the 9 feet arch, already described, for the Collagh Burn; and a new water course is to be built, as shown on the plan of the Railway at X Y.

CROSSING OF PARISH AND OCCUPATION ROADS.

Not already described as requiring Bridges.

The parish Road by Lodge to Slamannan is to be raised 1 foot, by earth and rubble pitching, laid by hand; the surface of which, to the depth of 4 inches, is to be covered with broken whinstone, 18 feet wide, neatly and evenly spread. The length to be 20 yards on each side of the Railway.

The parish Road to Slamannan at Blaquharson is to be raised 1 foot 2 inches, by a rubble pavement, placed on 6 inches of earth filling; and the pavement is to be covered with broken whinstone, 4 inches thick, neatly spread and formed. The width to be 18 feet and the length 20 feet on each side of the rail.

Where the Railway crosses the road to Slamannan by Pirney Lodge, this road is to be raised 9 feet 9 inches, as shown on the general section at G, and carried on the level over the Railway. When the filling is completed, the surface of the road is to be carried up with 6 inches of properly broken whinstone, formed to a proper curve, and cross section, 18 feet wide.

A post and rail Fence is to be constructed on each side of the roadway, similar to that described for the Railway; only that there is to be a double row of posts and rails, to protect the quicks from cattle.

GENERAL OBSERVATIONS.

All the Stones required for the blocks, stone dykes, and bridges, shall be provided by the Contractor; which stones shall be taken from Craig Mochan quarry, Arden quarry, Avon Bridge quarry, upon payment of per fall, or from any other quarry that may be approved of by the Engineer or Inspector.

As it is of the greatest consequence that the Blocks should be provided and dressed in the quarry as early as possible, so as to be examined by the Resident Engineer from time to time, previous to their being carried to the work, by which means he has time to examine and reject those that are defective in size or quality, the Contractor is to bind himself to furnish every month, or forfeit a sum of 10*l.* for any such omission.

The Stones required for the Ballasting, boxing, drains, and dwarf walls, may be got from Arden, or any more convenient quarry that may be discovered near the work, upon payment of per cube yard.

The Contractor is to furnish and provide all Materials, Centering for the bridges, arches, and culverts, with Waggons, tools, barrows, and implements of every kind and description necessary for the proper execution of the work, with the exception of the rails and chairs as above mentioned.

The work shall be proceeded with so soon as the Contract (to follow hereupon) is subscribed to by the parties. The whole work herein specified shall be completed and perfectly finished before the 1st of .

Until the Work be finally approved of by the Engineer, and taken off the hands of the Contractor, he shall maintain all the works, stone, masonry, and iron, and shall keep all the fields properly fenced through which the road passes, so far as his operations extend; and if by neglect of the Contractor, his workmen, or others, damage shall arise by cattle straying, or otherwise, the amount thereof shall be withheld by the Company from the amount of the Contract price for the work.

The Company is to pay all Temporary Damage on the line of road, in so far as the ground to be permanently occupied extends; but the Contractor shall be liable for damage done by himself or workmen by quarries, roads, or any other operation beyond the line of road.

The Company reserve power to make such alterations, or deductions from, or additions to the work, as they may think proper, without violating the Contract to follow hereupon: Provided such deviations or alterations be made in writing, signed by the Engineer and Clerk of the Company; allowance being made in

either case for the same, as shall be fixed and determined between the parties by the Company's Engineer.

The whole work herein specified shall be done in a substantial, neat, and workmanlike manner, to the satisfaction of the Engineers to the Company.

In order to secure the proper laying and fittings of the Blocks and Sleepers, rails, and chairs, for the Permanent Road, the Contractor shall be bound to appoint an experienced Foreman to conduct that part of the work, and one that shall be approved of by the Company's Resident Engineer.

Security will be required for the proper performance of the work, and the price will be paid by monthly instalments, as the work advances, and as the Superintendent shall certify, deducting one-tenth from the amount of such certificate of the work actually executed, and measured in detail by the Superintendent. The balance arising from these deductions to be paid the Contractor, on the certificate of the Engineer, every three months, or as often as he inspects the works.

The Contractor shall also be bound to maintain the Bridges, drains, and other masonry executed by him, for the space of one year after the completion of the work.

Persons desirous to contract for the work are to state a lump sum for executing the whole work herein specified. The Engineer for the Company may, however, call for the detailed estimate of the Contractor approved of by the Company.

Should Stone be found in the Cuttings, or along the line, fit for blocks or bridges, a corresponding deduction is to be made from the lump price mentioned for the same, as the Company's Engineer shall consider fair and reasonable between the parties.

The Company will not pledge themselves to accept the lowest offer for the work, unless the person so offering be otherwise approved of.

Sealed Proposals for the work, addressed to the Committee of Management, will be received at the office of Messrs. Mitchell, Graham and Mitchell, 36, Miller Street, Glasgow. (Signed)

JOHN MACNEILL.

London, 3*d August*, 1836.

[All clauses referring to the Stone blocks and Stone bridges, centering, &c., were omitted, and the Contractor was not required to include the same in his estimate; also, the clauses relating to Security required, &c., were omitted.—*Editor.*]

LANCASTER CANAL.

JOHN RENNIE, Esq., Engineer.

Aqueduct over the River Lune. Vide Plates 68 and 69.

A very elegant Work. We cannot do better than avail ourselves of Mr. Peter Nicholson's description, as given in his Architectural Dictionary; merely observing that the aqueduct, like all the works of its great designer, maintains at the present time the distinguished position which Mr. Nicholson has so justly assigned to it.

" Mr. Rennie also constructed the Aqueduct Bridge over the river Lune, at Lancaster, which is considered as one of the most magnificent works of the kind extant. At the place where it is built, the water is deep and the bottom bad,—the foundation is therefore laid 20 feet below the surface of the water, on a flooring of timber resting on piles; the Arches are five in number, each of 70 feet span, and rise about 39 feet above the surface of the water. It has a handsome Cornice, and every part is finished in the best manner. The total height, from the surface of the river to that of the canal, is 57 feet, and the canal admits barges of 60 tons burden to navigate upon it. The foundation alone of this building cost £15,000, and the superstructure more than double that sum, although the stone was obtained from a quarry less than a mile and a half from the spot."

Plate 69 shows the Works in state of execution, as they appeared in September, 1795.

The Frontispiece (Plate 70) represents the Bridge over the Grand Junction Canal at Blisworth, upon the London and Birmingham Railway, with the works in state of progress as they appeared in the month of September, 1837.

LIST OF PLATES.

T. C. Savill, Printer, 4, Chandos Street, Covent Garden.

SECOND SERIES

OF

RAILWAY PRACTICE:

A Collection

OF

WORKING PLANS AND PRACTICAL DETAILS OF CONSTRUCTION

IN THE

PUBLIC WORKS

OF THE MOST

CELEBRATED ENGINEERS:

COMPRISING

ROADS, TRAMROADS, AND RAILROADS;
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CANALS, LOCKS, SLUICES, & THE VARIOUS WORKS ON RIVERS, STREAMS, &c.;
HARBOURS, DOCKS, PIERS AND JETTIES, TUNNELS, CUTTINGS AND EMBANKMENTS;
THE SEVERAL WORKS CONNECTED WITH
THE DRAINAGE OF MARSHES, MARINE SANDS, AND THE IRRIGATION OF LAND;
WATER-WORKS, GAS-WORKS, WATER-WHEELS, MILLS, ENGINES,
&c. &c.

BY

S. C. BREES, C.E.

LATE PRINCIPAL ENGINEER AND SURVEYOR TO THE NEW ZEALAND COMPANY,
FROM THE YEAR 1842 TO 1845.

Second Edition.

WITH ADDITIONAL EXAMPLES.

LONDON:
JOHN WILLIAMS AND CO.
LIBRARY OF ARTS, 193, STRAND.
1847.

PREFACE

TO

THE SECOND EDITION.

It is always satisfactory to an Author to find the public appreciate his labours, but more especially when his work is of a professional character, and expensive to get up. It was not without some risk, that the Editor completed this "Second Series of Railway Practice" originally, and he is happy to state that it has met with every encouragement from the Engineering profession.

Once more the Editor returns his thanks for the kindness of the several engineers who have contributed to the present volume, including—

ROBERT STEPHENSON, ESQ., M.P.
JOSEPH LOCKE, ESQ., M.P.
JAMES WALKER, ESQ.
GEORGE RENNIE, ESQ.
SIR JOHN RENNIE.
SIR JOHN MACNEILL.
WILLIAM CUBITT, ESQ.
CAPTAIN W. S. MOORSOM.
JOSEPH GIBBS, ESQ.
GEORGE WATSON BUCK, ESQ.
CHARLES VIGNOLES, ESQ.
THOMAS J. WOODHOUSE, ESQ.
ROBERT NICHOLSON, ESQ.
W. C. T. WEST, ESQ.
CHARLES DAVY, ESQ.

PREFACE.

The First Series of "Railway Practice" having been very favourably received by the profession, the publisher felt warranted in commencing a Second, but owing to untoward circumstances at the time was prevented proceeding with it; the Editor has, therefore, been induced to produce the work at his own cost, rather than that it should have been left unfinished.

In presenting the present volume to the notice of the profession the Editor begs to remark, that it consists simply of a collection of "Useful Examples in Civil Engineering," the works of eminent men; and all he has attempted has been to do justice to the various subjects, and to economise the time of the reader by making the illustrations as clear and explicit as possible; throwing forward the most essential points in the details, and keeping all subordinate parts at a due distance; and he considered it better to insert the specifications in their original form, than to give the matter in another shape, notwithstanding the appearance of conciseness which might be attained by the latter plan.

Since the object of the work is merely to ILLUSTRATE an important branch of the profession, and one little before pourtrayed, at least in a practical point of view, if he has succeeded in accomplishing this, and has moreover produced an useful book of reference for the student, he trusts it will not be found unacceptable.

To the numerous gentlemen who have so kindly assisted and cooperated with the Editor, comprising the engineers of the works represented—to each of those gentlemen individually he begs most respectfully to acknowledge his obligations, and to return his most grateful thanks.

12, South Square, Gray's-Inn,

May 1*st*, 1840.

INTRODUCTION.

The science of Civil Engineering is one of those which have arisen from the increased demands of the community, in consequence of the advance of civilization in modern times, and from the quiet workings of the wealth of nations in times of peace; hence those countries most secure from the presence of war are generally in better condition, as respects internal improvements, than others which are subject to be overrun by it.

Engineering, although of such paramount importance to the prosperity of a country, was but little understood or practised formerly, more especially for purposes of a civil nature, its application being almost exclusively confined to the service of warfare and military erections, such as fortifications, and their accompanying works; yet, it must be admitted that civil engineering has existed during all ages, and in most countries, in one shape or other.

The subject of roads was well understood by the Romans; in fact, they may be said to have excelled the moderns in this department, although it should not be forgotten, that the weight to which ancient roads were subjected was light compared to that of modern carriages, the traffic upon them was also much less, and their cost was extremely great, no expense whatever having

been spared upon them. Canals were also constructed by the Romans, but not to the same extent as roads: they were used by the Egyptians also, and by the Chinese, from a very early period, as generally supposed; but they were not adopted by the moderns until the sixteenth century. The erection of bridges was probably among the earliest instances of civil engineering, roads only excepted: the aqueducts and bridges of the Romans are among their most celebrated works; yet, notwithstanding the costliness of these and other works of the ancients, all are comparatively inefficient, compared with many modern engineering works of a similar nature; but the materials employed by them were, from some cause, superior to those now used, and the excellence of their cement may be instanced, in corroboration of this remark. Our forefathers in the middle ages were also well acquainted with the properties of building materials.

From what has been stated, it follows that the profession of civil engineering is one of modern times, originating from the necessities of the art: the profession of architecture was anterior to it, although far from assuming a decided character in all ages, and the date of its practice in this country is not considerably in advance of that of engineering, the latter being formerly included in the architectural department; but it was then very limited, comprising merely the drainage of fens, which is of early origin, the navigation of certain rivers, the erection of bridges, and the formation of the New River, by Sir Hugh Myddleton, for the supply of the city of London with water, almost completes the list, up to the period of the introduction of canals by the celebrated Brindley, in the year 1758, when engineering received a grand stimulus. The subject of machinery was also making rapid progress about the same period, for the steam-engine being then very generally employed, afforded extended means in mining, and such like operations, which had previously existed in a very contracted state. The necessity of exclusive attention to the subject of civil engineering then became apparent, and which led ultimately to its severance from architecture: from henceforward it became a separate profession, partaking with the latter in some

general principles, but comprehending a more extended range; and this dissolution may be easily accounted for, when the increased practice and importance of both professions at the time is considered.

In the early stage of the profession its followers may be styled self-taught, or men possessing great natural abilities for the subject, among whom may be mentioned Brindley and Smeaton; also, Jessop, Rennie, and Telford. To enumerate the many celebrated works of these great men, would be to form a list of almost all our public works since the period of their commencement; suffice it to say, that by the talents of these men civil engineering received a wonderful impulse: and it is further gratifying to its professors, to know that its influence is becoming yet more extended, as the many new applications of means for the accomplishment of various purposes, and the improvements effected by it every day, embracing the subject of roads, canals, harbours, docks, drainage of fens and marine sands, water-works, gas-works, mines, bridges, and railways, with the several collateral branches connected with each fully prove: and all scientific men agree, that far greater advantages will yet result from the practice of it. There is scarcely any department of engineering that can be described as perfect; improvement follows improvement, and the work last executed is always superior to the preceding.

It is therefore highly necessary that the student in civil engineering should be acquainted with the latest mode of construction employed, for although much may be derived from theory in all speculative sciences, yet, where great capital is at stake, it behoves those who have the direction of the works to be careful not to trust too much to new theories, but to be guided more by practice and experience; and upon referring to most great discoveries connected with engineering, it will be found that they have generally resulted from practice moving, as it were, step by step; hence the great desire of mathematicians to make the theory agree with the practice; yet we must, in justice, admit the value of correct theories on scientific subjects.

The practice of civil engineering, at the present time, comprises the construction of roads, tramroads, and railroads; the erection of bridges, aqueducts, and viaducts, also wharfs, warehouses, roofs, and sheds; the preservation of the navigation of rivers, streams, &c.; the execution of canals, locks, sluices, &c., also tunnels, cuttings, and embankments; the formation of harbours, docks, piers, and jetties; the drainage of marshes and marine sands, and the irrigation of land; the execution of water-works, gas-works, water-wheels, mills, engines, &c.; the working of mines, &c.; together with the general direction of all engines, machines, and contrivances, contingent or connected with any of the above-stated departments, although the absolute construction and manufacture of the latter are conducted by another class, who may be styled "Mechanical Engineers;" and there are instances of the same individuals practising in both departments.

Having enumerated the several branches in the practice of civil engineering, we have now only to remark, that it is the intention of the present work to illustrate them, which we have endeavoured to effect, by a series of suitable examples in each.

GREAT WESTERN RAILWAY.

I. K. BRUNEL, Esq., Engineer.

The Frontispiece represents the Bridge over the Thames, at Maidenhead, on the line of the Great Western Railway.

The two river arches are each 128 feet span, with a rise of 24 feet 3 inches, and there is a towing-path arch on each side 21 feet span, and three land arches each of 28 feet span. The whole structure is built of brickwork, except the cornice and coping, which are of stone; the two principal arches are the largest yet constructed of brickwork, and are turned in cement and in half-brick rings; the thickness of the arch at the springing being 7 feet 1½ inches, and each of them are gradually diminished towards the crown, where they are made 5 feet 3 inches.

This bridge has created a great sensation in the scientific world, and many have been the predictions respecting it; a portion of the eastern river arch was taken down, and rebuilt: after the period of its first erection, certain defects of workmanship having appeared in the crown, where some of the rings had partially separated from each other, extending for a distance of two or three yards on each side of it, and the cracks were about half an inch wide, but the whole is now executed thoroughly strong, and to the true form required; it is, therefore, likely to remain a lasting monument of the skill of its engineers and builders.

In constructing arches of great span in brickwork, it becomes a point of immense importance to secure good materials and workmanship; this bridge may be said to have been wholly accomplished by the great care bestowed upon it in this respect; had the cement or bricks proved to have been inferior, the whole must have come down, it may, therefore, be described as an extremely hazardous undertaking, and one which few men would have risked.

LONDON AND CROYDON RAILWAY.

JOSEPH GIBBS, Esq., Engineer.

This railway forms a junction with the Greenwich railway, at about a mile from the terminus at London Bridge: the Act was obtained in the year 1835, and the works were shortly afterwards commenced.

The mode of constructing the line and contingent works differs from the usual plan of execution, but the alterations are of such a nature that the engineer could safely make, and are within the bounds of prudence, although nothing is more injudicious than the premature adoption of new systems, more especially when employed upon an extensive scale; as improvements in engineering have hitherto proceeded step by step, the safest way, most undoubtedly, must be to continue in the same course, and to perfect those systems which have already been in use, as in the present case, in preference to commencing altogether *de novo* upon a different plan: in the former, the full benefit of experience is taken advantage of.

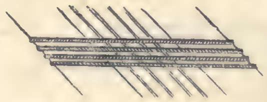
The rails are laid bodily upon beams, as shown in the plates, and thus have a continuous bearing throughout; the system of securing them is very simple, and has been found to answer exceedingly well, it may be called the most perfect plan of simple continuous bearings up to the present period; some of the bridges are also in a new style of construction. There is an oblique bridge formed by separate walls, thus,  and stone landings are laid across the paces between them at the top, upon which the road is laid, instead of the usual expensive process of forming the arch and abutments aslant.

TABLE OF GRADIENTS.

Miles.	Chains.	Links.	
1	60	0	*(Greenwich railway).*
0	41	15	falling 1 in 4.744
0	57	63	„ 1 „ 1.311
2	50	36	rising 1 „ 100
0	34	40	level „ „ „
0	34	55	falling 1 „ 2.591
1	4	70	rising 1 „ 660
0	46	39	level „ „ „
1	29	13	falling 1 „ 660
0	41	50	rising 1 „ 823
0	40	97	level „ „ „

The earth employed in forming the embankments was sorted; and the upper stratum, or yellow plastic clay, was taken to spoil, the blue arenacious clay only being used; the extra expense accompanying this has been amply repaid, a slip not having occurred on any of the embankments, although they are formed throughout the line with side slopes of 2 horizontal to 1 vertical. The cuttings in clay are, for the most part, at slopes of 2 to 1, except in places where the depth is less than 10 feet, where they are made $1\frac{1}{2}$ to 1, and in the diluvial deposits of gravel, near Croydon, they stand well at $\frac{3}{4}$ to 1, and at 1 to 1.

RADII OF CURVES ON MAIN LINE.

1	curve	of 142	chains	radius.
1	„	140	„	
1	„	112	„	
2	„	90	„	
6	„	80	„	
4	„	60	„	
1	„	20	„	

The curve of twenty chains radius is situated near the Croydon terminus, and is never traversed at a speed exceeding 15 miles per hour.

The curves in the stations practicable for the working of six-wheeled engines, vary from 1.050 to 250 feet radius; an engine will readily traverse a curve of the latter radius, if the outer rails be lifted $1\frac{1}{2}$ inches higher than the inner ones.

PERFORMANCES OF ENGINES.

The Surrey engine, with one carriage attached, traversed the distance, between London and Croydon, $10\frac{1}{2}$ miles, on the 2nd of June, 1839, in sixteen minutes, including starting, easing off at the junction with the Greenwich railway, ascending the inclined plane (without an assistant engine), and stopping, which gives an average of 39.37 miles per hour throughout.

The highest measured velocity attained by an engine attached to a train of carriages on this line, was 50 miles per hour, in which case there were six carriages, containing 120 passengers in the whole. The highest measured velocity attained by the above-mentioned train in descending the inclined plane of 1 in 100, was 47 miles per hour, which was from the force of gravity only; but the average of several journeys seldom exceeds $25\frac{1}{3}$rd miles per hour.

The average velocities of several trials in ascending the inclined plane with the above train, were as follows:—

Time in Minutes.	Distance in Miles.
0	*(Foot of plane.)*
1	$\frac{1}{4}$
$\frac{3}{4}$	$\frac{1}{2}$
$\frac{1}{2}$	$\frac{3}{4}$
$\frac{1}{2}$	1
$\frac{1}{2}$	$1\frac{1}{4}$
$\frac{1}{2}$	$1\frac{1}{2}$
$\frac{1}{2}$	$1\frac{3}{4}$
$\frac{1}{2}$	2
$\frac{1}{2}$	$2\frac{1}{4}$
$\frac{1}{2}$	$2\frac{1}{2}$
$\frac{1}{2}$	$2\frac{3}{4}$
$6\frac{1}{4}$ minutes.	$2\frac{3}{4}$ miles.

which gives an average velocity of 26.40 miles per hour.

The train had not the help of an assistant engine; and it started from a state of rest in each instance, without any lead whatever.

The average time employed in performing the journey of $10\frac{1}{2}$ miles, both up and down, is $30\frac{1}{2}$ minutes, including starting, stopping at five intermediate stations, and easing off at the junction with the Greenwich railway. The

average time occupied in stopping at the whole of the stations is 2½ minutes, or half a minute at each, during which period the engine is completely idle.

There is an inclined plane rising 1 in 50, and 330 yards in length, communicating with the main line from the Surrey canal wharf, on which there are three curves—one of twenty chains radius, and two of 600 feet radius—and a six-wheeled engine, weighing thirteen tons, drew itself and tender up this incline with a load of 11.33 tons, at a velocity of 7½ miles per hour, having a lead of 125 yards to the foot of the plane; the same engine, starting on the plane without any lead, took up 10.83 tons, at a velocity of 6.18 miles an hour, the diameter of the cylinder of the engine being 13 inches, with an 18 inch stroke, and the diameter of the driving wheels 3 feet 6 inches.

Plate 2.—Represents the method of forming the Permanent way; the transverse sleepers are of oak, and the longitudinal beams are of Memel fir, and each of them are subjected to the process denominated "Kyanizing;" the longitudinal sleepers are secured to the transverse beams by spring bolts, and to the rails by wood screws, as they are termed, or screws in which the bodies taper, but not the worms, which continue straight, a layer of patent felt being placed between the sleeper and the flanges.

Plate 3.—Bridge for Occupation Road on Deptford Common. There are several bridges built after this plan upon the line, and they have a very elegant appearance.

DETAILS OF THE

LOCOMOTIVE ENGINE NAMED THE "CROYDON,"

For assisting the Trains up the Inclined Plane, of 1 *in* 100, *on the Croydon Railway.*

GEORGE AND JOHN RENNIE, Esqs., Engineers.

Plate 4.—Side Elevation of engine.

Plate 5.—Plan of ditto.

Plate 6.—Transverse Sections of ditto, taken through the boiler and through the cylinders and smoke box.

Diameter of cylinder		0 ft.	13 in.
Length of stroke of piston		0	18
Diameter of driving wheels		5	6
Ditto smaller wheels		3	6
Ditto of tubes	No. 117	0	$1\frac{7}{8}$
	No. 4	0	$1\frac{5}{8}$
Length of ditto		8	5
Fire box	Length	3	0
	Breadth	3	7
	Depth	4	0
Boiler, (cylindrical part)	Length	8	0
	Diameter	3	$3\frac{5}{8}$
Chimney	Height	5	6
	Diameter	1	2
Steam passage		0	$1\frac{3}{8} \times 8\frac{5}{8}$
Diameter of blast pipe		0	3
Weight of engine		13 tons.	
Ditto with water		14 ,,	5 cwt.

The "Croydon" locomotive was constructed in the month of September 1838, and was worked for four months with scarcely any repairs, being employed twelve hours per day, viz., from 6 o'clock in the morning until 6 in the evening, performing about 170 miles daily; and it accomplished a speed of 28 miles an hour up the inclined plane, with 12 ballast waggons attached to it, the weight of which was 43 tons.

The cylinders are situated on the outside of the wheels, as shown on the plates, the piston rods working in slides, and the connecting rods are fixed to the naves of the driving wheels, the latter being coupled to the foremost wheels, whereby the power of adhesion of the engine is increased.

Messrs. Rennie also constructed another locomotive engine for this railway, of precisely similar form and dimensions to the Croydon, which was named the "Archimedes."

BIRMINGHAM AND GLOUCESTER RAILWAY.

CAPTAIN W. S. MOORSOM, ENGINEER.

PLATE 7.—Plans, Elevations and Sections of bridge, Nos. 5 and 6, at Cheltenham, *(see Specification of same.)*

PLATE 8.—Ditto, ditto, Details of iron girders and framing, *(see Specification.)*

PLATE 9.—Plans, Elevations and Sections of bridge, No. 35. Bredon Contract.

PLATE 10.—Elevations and Sections of Tewkesbury Depôt. Contract 15 G. *(See Specification, &c. of same.)*

PLATE 11.—Ditto, ditto, Plans of ground and one-pair floors.

BIRMINGHAM AND GLOUCESTER RAILWAY.

CONTRACT, No. 12, G.

Lansdown Extension. Bridges 5, 6, *and* 27, *Cheltenham. Masonry.*

SPECIFICATION of the several works to be performed in making and completing the masonry in the girder bridges to be built for carrying the Gloucester turnpike road and tramway, Nos. 5 and 6 on the plan, and the Arle road, No. 27 on the plan, over the railway in the parish of Cheltenham, in the county of Gloucester.

CONDITIONS ON WHICH CONTRACTS ARE TO BE MADE.

1. The contractor is to furnish all materials (with exception of stone), implements, and tackle that may be required during the execution of the works.

2. The contractor is to execute the whole of the works, as described in the specification, according to the working plans, sections, and drawings, to the satisfaction of the company's principal engineer and resident assistant engineer, who shall have power to reject materials which are not of the best quality, and to take down imperfect workmanship. The principal engineer is to decide disputes, if any arise; and the works are to be executed within the periods limited, either in whole or in successive portions, as stated in the specification

3. The contractor to receive fortnightly 90 per cent. of the amount due for works performed. The balance to be retained by the company until after completion of his contract, under certificate of the engineer-in-chief, and to be then paid to him.

4. The work to be measured by the engineer, and the payment to be made by the company, through their secretary or pay-clerk, upon the certificates of amount due, signed by the engineer-in-chief.

5. Copies of the specification, &c., and of the tender annexed, to be deposited with the resident assistant engineer. Contractor to have access to them.

6. In case of workmen employed or materials provided by contractor not being sufficient for completion of the works within the period named, contractor shall, upon notice from the company, provide such additional workmen or materials as the principal engineer shall deem necessary; and, in default, company shall employ such additional workmen or materials at the cost of the contractor, and may also deduct their wages and cost out of monies due to the contractor, so far as the same may be sufficient for that purpose.

7. The company to have power to remove any persons in employ of contractor on the line, after notice thereof being given to the contractor.

8. The contractor is to deliver, at the office of the resident assistant engineer, an account, every fortnight, of the number of artificers and other workmen employed the preceding fortnight, according to a form to be furnished, or to pay £2. on default; also to deliver, at the same time and place, an acknowledgment, under the hand of the sub-contractors, or foremen, or overlookers, or head-workmen, that every person engaged by or under the contractor, has received the whole amount of his demand upon the contractor up to the date of such acknowledgment, or in case of any exception, to state the reason for such exception.

9. The contractor not to use adjoining lands without consent, in writing, of the engineer-in-chief.

10. The contractor to dispose of spoil as directed by the principal engineer.

11. The contractor not to make bricks, &c., without consent of the engineer, in writing; nor to use the land for any purpose, nor upon any spots to which prohibitions attach in the Act.

12. If temporary roads be necessary, engineer to set them out; contractor not to deviate therefrom.

13. The contractor to make satisfaction and compensation, as required by the Act, to all owners and occupiers, for damages by trespass of himself or his men.

14. The contractor not to make sub-contract without the consent of the company, except as to labour only.

15. Alterations or additions to works not to be executed without written authority, signed by the engineer-in-chief or resident engineer. Works omitted by the same authority to be deducted for, according to the scale established in the "Schedule of Prices."

16. The contractor, if required by the company, is to pay the sub-contractors and workmen their full wages (vouched as stated in clause 8) on the day to be appointed by the company, and in presence of the company's agent, in such places as the company may appoint, and no other. The same rule to apply to all payments made by sub-contractors, and company to have the power of dismissal in case of non-compliance.

17. The contractor to employ no men on Sundays, except on such works as are certified in writing by the engineer-in-chief, or resident engineer, to be absolutely necessary. The company to have power to dismiss any man found so employed on Sundays, except under this certificate.

18. The contractor not to retail, either directly or indirectly, (without permission of directors) any article of consumption to the workmen.

EXTENT OF CONTRACT.

This contract comprises the formation and completion of the wing walls and abutments up to the level of the timber bearing plate to be placed on the latter, and may be extended at the option of the company's chief engineer; to be included, on the same terms and conditions, the entire completion of the masonry of these bridges, including coping, string courses, and moulded imposts, caps, &c.

It will comprehend the following works, viz.:—

1. Excavating for foundations to such depth as in the judgment of the engineer shall be found requisite, and as shall be set out by him; or by such person as he shall appoint.
2. Building with clure-hill oolite stone, laid in mortar, the foundations and upper walls of the abutments and counterforts, piers and wing walls, up to the level of the springing plate.
3. Filling into the walls as they are carried up, and backing to them with gravel or other dry material from the neighbourhood, and approved by the engineer

Also the following extra works, if required to be executed, viz.:—

1. Completing the parapets to the wing walls, and carrying up the latter to the height shown in the drawings; as also the parapet walls over the arched girders.
2. Dressing and setting the coping, and caps, and moulded imposts.
3. Turning 9 inch coombs* in brick between the girders, and carrying up side walls on the flanges, to keep their springing line at its proper level.
4. Spreading a course of concrete over the whole surface of the bridge to a thickness of not less than 3 inches over the crown of the coombs.

DRAWINGS AND SPECIFICATIONS.

The preceding enumerated works, and mode of execution, are described in the specification of each particular work, and their forms and dimensions are represented on the accompanying drawings, which are referred to in this specification; but should any discrepancy exist between the scale attached and the written dimensions, or between the drawings and specifications, or any ambiguity in them, the same are to be referred to the engineer-in-chief, whose decision shall be conclusive.

Also anything contained either in the drawings or specifications shall be equally binding upon the contractor, as if it were contained in both.

The written dimensions upon the drawings are to be taken in all cases in preference to the scale attached.

The drawings attached to this contract contain a plan and elevation of the bridges when finished, and sections of the wings and abutments, and of the parapet wall over the arched girder, showing the method of fitting the stones to the flanges of the upper and lower ribs of the principal girders; also enlarged sections of the cap stones, coping and mouldings to the pilasters, and a section showing the brick coombs,* and concrete laid over them.

* Forest of Dean landings were substituted for brick coombs in the bridges Nos. 5 and 6.

FOUNDATIONS.

The contractor is to excavate for the foundations of all the walls; and, in cases of the foundation requiring, in the opinion of the engineer, to be carried lower than is represented in the drawings, the contractor shall execute the same, where so directed, and shall be allowed for the additional work, according to the prices set forth in the "Schedule, No. 1.;" and he shall be allowed in like manner for concrete placed under the foundations, or in other situations, by the direction of the engineer, in cases where the same has not been specified or shown on the drawings.

When the excavation is complete, the ground is to be well rammed before laying any masonry, if required by the engineer.

MASONRY.

1. The footing courses are to consist of large flat stones, with fair beds and joints squared so as to lie close, they are to be laid full in mortar, and properly bonded vertically and horizontally, and of the heights and onsets figured on the drawings.

2. The foundations of the wing walls will rise along the slopes of the railway in successive level steps, as shown on the drawings.

3. The upper walls shall be carried up in level courses on each side of the railway, and each side is to be built if so required at the same time. They shall consist of sound rubble masonry, without regard to courses, and to be faced with ashlar, axed on the face in the best manner.

4. The ashlar must be dressed in courses, not less than 8 inches in height; width of top bed not less than 16 inches, and length not less than 2 feet; the beds to be full and square for their whole depths, and the joints for a distance of not less than 8 inches from the face.

5. The faces are to be fine axed or chopped, at least equal to the best portion of a sample to be seen on application to the sub-engineer in charge of the works at Cheltenham.

6. The face work shall be laid with a header to every three stretchers, on a fair and even bed of mortar, the joints pointed, and the whole grouted full in.

7. No joint of mortar on the face shall exceed $\frac{1}{8}$th of an inch thick; and if the outer arrises of a stone are imperfect it must be removed and redressed, and on packing or pinning will be allowed.

8. The vertical bond shall be such, that the headers shall lie in the interior

(and as near its centre as may be), between the headers in the course below and the lengths of the stretchers so regulated under the limits already assigned, that the vertical bond of the joints shall not be less than half the height of the course below.

9. The quoins, cheeks, and internal angles must be carefully cut, and the stones composing them bonded with the strictest attention.

10. The backing of uncoursed rubble work shall be carried up at the same time, as the face of the stones shall be laid in a thick bed of mortar, and shall be properly selected as to size.

11. Thorough stones shall extend from the face to the back of the walls at intervals in the abutments, not exceeding two spaces of headers and stretchers horizontally, nor the height of three courses vertically, and in the wing walls not exceeding three spaces of headers and stretchers horizontally, nor the height of four courses vertically, and these thorough stones must be properly arranged for bond.

12. The counterforts must be built up with the walls, and well bonded in with them.

13. In carrying up the abutment walls cast iron plates, 18 inches square and $1\frac{1}{2}$ inch thick (which will be furnished by the Railway Company), shall be built in, so as to have their lower surfaces 7 feet 2 inches from the top of the wall, when finished, to the under side of the springing plate; the hole which perforates these plates shall be 15 inches from the face of the wall; wooden trunks, for the holding down bolts, 2 inches square in the clear, shall be built in the thickness of the wall, standing plumb over the holes in the plates. Holes, 9 inches square on the face and 2 feet deep, shall be left under the cast iron plates; and these holes shall have stones neatly dressed and fitted to them, but which may be removed when it may be necessary to have access to the ends of the holding down bolts.

14. When up to their proper height the abutments shall be levelled out, and the timber bearing plates shall be well bedded by the mason.

15. The abutments and wing walls shall be filled into and backed with clean dry gravel or other material approved by the engineer, and procurable in the neighbourhood; as they are carried up the filling and backing shall be well rammed with punning malls, in courses not exceeding 18 inches thick.

16. The parapets are to be built solid in header and stretcher without above. One header to every two stretchers on the face, and dressed on both faces above the intended level of roadway; they are not to be built until the concrete is laid over the bridge.

17. Nine inch brick coombs,* laid in roman cement, are to be turned between

* Forest of Dean landings were substituted for brick coombs in the bridges Nos. 5 and 6.

the girders, in such manner that the crown at the back shall be level with the upper flange of the middle girder at its middle point; and, in order to keep the springing courses level through, side walls are to be built upon the flanges of the girders of bricks on their flat sides, the lower courses being properly cut or rubbed to fit the curve of the girder as it falls.

18. The open spaces at the ends are to be filled up with 13 inch brick walls, in english bond, laid in cement.

19. A course of concrete, not less than 3 inches thick over the crown of the coombs, shall be spread uniformly over the whole surface of the brickwork, and rammed hard.

20. The contractor will be required to take every necessary precaution for the security of the temporary tramway bridge during the progress of the work, as well as for the security of the public, by keeping up the fencing, and watching and lighting, if requisite.

COPING

Shall be of the form and dimensions shewn upon the drawings; each stone shall not be less than 3 feet in length, unless directed otherwise by the engineer; and each stone must be dowelled and leaded to the adjoining one, and well throated. The string courses, parapet walls, and coping, shall not be put on until after the centres are struck, which shall not be done in any case without the permission of the engineer. Caps to the piers to be of one stone only.

The mouldings to the pilasters must be neatly worked with the chisel or tool, and there shall not be more than two stones in each impost in length, and the bottom beds when set must have a solid bearing on the wall of at least 18 inches.

MORTAR.

The mortar shall consist of fresh burnt lime of the best quality (to be approved by the engineer), and clean sharp river sand, mixed in the proportion of three measures of sand to one of lime, or in other proportions if deemed necessary by the engineer; they must be mixed in a dry state, and well tempered, by passing through a pug-mill, with a proper quantity of water.

CONCRETE.

The concrete shall consist of good coarse gravel or broken oolite stone not larger than a hen's egg, mixed with unslacked lime in the proportions of 5 measures of gravel or stone to 1 of lime, and beat up with a proper quantity of water.

The lime must be thoroughly ground to powder before being mixed up with the gravel. And it shall not be mixed up till wanted for use.

ROMAN CEMENT.

The roman cement shall be of the best quality, and shall be mixed with an equal quantity of clean sharp river sand; it shall be mixed immediately before being used, and none of it shall be employed which has become hard or set.

GENERAL STIPULATIONS.

The general regulations for the observance of the contractor are set forth in the printed form of " Conditions" at the commencement of this specification, and to them the contractor is referred.

Should it become necessary in the opinion of the engineer at any time during the progress of the works to increase, diminish, or alter the form or dimensions of any part of the work, the contractor shall comply with any order he may receive to that effect in writing from the engineer; the addition, diminution, or alteration to be allowed for according to the rates stated in the " Schedule of Prices" for the particular work annexed to the tender, and the general contract not being vitiated thereby.

The contractor is to provide all the necessary machinery and materials for thoroughly draining the works during their progress, whether by drifting, pumping, or other means. Also all planks, waggons, barrows, tools, and materials whatsoever for temporary ways that may be required in the execution of his contract; all of which are to be of a quality and construction approved by the engineer.

Any materials which the engineer shall deem insufficient or improper to be used shall be removed from the ground by the contractor within three days after notice has been given him in writing to that effect; and in case of his failing to remove such materials in the time above specified, the engineer shall have the

power to cause them to be removed by the most convenient means, and at the contractor's expense.

The contractor will be held liable by the company for all damage to adjoining lands done by trespass of the people in his employ.

The whole of the work executed under the contractor is to be of the soundest description, done in a substantial and perfect manner.

The contractor will be at liberty to use the quantities of the several descriptions of work from which the engineer's estimates have been made, without the engineer being any further pledged for their accuracy.

In case of foreclosure of the contract, the contractor shall forfeit all claim to the balance of monies, if any then due to him from the company, upon this contract.

PROGRESS OF THE WORKS.

The work shall be commenced immediately, and shall proceed at such rate as to insure the completing the abutments and wings up to the level of the timber springing plate, within nine weeks from the date of contract; and if this rate of progress is not complied with, it shall be at the option of the engineer to close this contract at any period during the same, upon giving a week's notice in writing to the contractor to that effect.

TENDER.

WE, Masons, of do hereby propose to execute the masonry of bridges, Nos. 5, 6, and 27, Cheltenham, according to the plans and specifications exhibited to us; and to maintain the same until delivered over to the engineer on completion of the contract; and provide all the requisite materials within the periods, and upon the terms and conditions mentioned and contained in the draft also exhibited to us, for the sum of *four hundred and eleven pounds eighteen shillings* (the springing course or impost is not included in this tender, as per instruction), allowance more or less being made at the above rate when the work actually performed is measured.

And we have in the "First Schedule," hereto annexed, set forth the prices of the different descriptions of work at which this tender is computed.

And we further propose to execute the several works in the said specification, denominated "Extra Works," at the prices affixed to each description of work in the "Second Schedule" hereto annexed.

And in case this tender shall be accepted, we hereby undertake to execute the agreement following to perform the works as above proposed, and under the conditions above referred to.

And lastly, we do hereby undertake and agree that in case the said agreement shall not be executed by us within one week from the date hereof, the said company shall not (unless they think fit) be bound by this tender, but the same shall be absolutely void, in case the company shall so think fit; nor shall they in that case be liable to any claim by us in respect of work then already done by us upon the said railway.

Witness our hands this day of 1838.

To the Directors of the

Birmingham and Gloucester Railway.

FIRST SCHEDULE REFERRED TO,

Containing a list of the prices of the several descriptions of works at which the accompanying tender is computed, the whole of the work being executed and completed according to the foregoing specification :—

1. The price of masonry set in mortar in foundations, abutments, counterforts, wing walls, and piers, &c., per cubic yard of masonry. . . . .
2. The price of excavating for foundations, at per cubic yard .
3. The price of concrete laid and set in place, at per cubic yard .
4. The price of mouldings to imposts, pilasters, &c., if not paid for as work under extension of contract for 2nd schedule below, at per foot run . . . . .
5. The price of backing and filling into walls punned, at per cubic yard. . . . . . .

SECOND SCHEDULE REFERRED TO,

Containing a list of the prices of the extra works :—

1. The price of masonry set in mortar in the parapets to wings, and also in parapets over arched girders, at per cubic yard.
2. The price of coping with cramps and dowelled joints run with lead weathered and throated, at per foot superficial .
3. The price of mouldings to imposts, pilasters, &c., at per foot run. . . . .
4. The price of concrete laid over the surface of the bridges, at per cubic yard . . . . .
5. The price of brickwork in coombs and wide walls to ditto, laid in cement, at per cubic yard. . . .

AGREEMENT.

WE, Masons of do hereby agree and undertake to execute, according to the specifications hereunto annexed, and subject to the conditions prescribed, the works on the Birmingham and Glouscester Railway, comprised in the permanent bridges, 5, 6, and 27, Cheltenham, amounting by computation to *four hundred and eleven pounds eighteen shillings*, more or less, at the average price of per cubic yard of masonry, and of other particulars to be paid to us according to the " Schedule of Prices" for each particular work hereunto annexed.

Dated this day of 1838.

For selves and partners ______________________

(Signed) JAMES P. RENNIE.
JOHN LOUGAN.

BIRMINGHAM AND GLOUCESTER RAILWAY.

CONTRACT FOR IRON-WORK IN BRIDGES.

Specification of the several works to be performed in making and completing the iron-work in the bridges hereinafter enumerated on the line of the Birmingham and Gloucester Railway.

CONDITIONS ON WHICH CONTRACTS ARE TO BE MADE.

1. The contractor is to furnish all materials, implements, and tackle, that may be required during the execution of the works.

2. The contractor is to execute the whole of the works, as described in the specification, according to the working plans, sections and drawings, to the satisfaction of the company's principal engineer and resident assistant engineer, who shall have power to reject materials which are not of the best quality, and to take down imperfect workmanship. The principal engineer is to decide disputes, if any arise; and the works are to be executed within the periods limited, either in whole or in successive portions, as stated in the specification.

3. The contractor to receive fortnightly 90 per cent. of the amount due for works performed less by the instalment due to the company on account of materials. The balance to be retained by the company until after completion of his contract, under certificate of the engineer-in-chief, and to be then paid to him.

4. The work to be measured by the engineer, and the payment to be made by the company, through their secretary or pay-clerk, upon the certificates of amount due, signed by the engineer-in-chief.

5. Copies of the specification, &c., and of the tender to be annexed, to be deposited with the resident assistant engineer and contractor.

6. In case of workmen employed or materials provided by contractor not being sufficient for completion of the works within the period named, contractor shall, upon notice from the company, provide such additional workmen or materials as the principal engineer shall deem necessary; and, in default, company shall employ such additional workmen or materials, at the cost of the contractor, and may also deduct their wages and cost out of monies due to the contractor, so far as the same may be sufficient for that purpose.

7. The company to have power to remove any persons in employ of contractor on the line, after notice thereof being given to the contractor.

8. The contractor not to make sub-contract without the consent of the company, except as to labour only.

9. Alterations or additions to works not to be executed without written authority, signed by the engineer-in-chief or resident engineer. Works omitted by the same authority to be deducted for, according to the scale established in the "Schedule of Prices."

10. The contractor to employ no men on Sundays, except on such works as are certified in writing by the engineer-in-chief, or resident engineer, to be absolutely necessary. The company to have power to dismiss any man found so employed on Sundays, except under this certificate.

11. The contractor not to retail, either directly or indirectly, (without permission of director) any article of consumption to the workmen.

EXTENT OF CONTRACT.

This contract comprises the formation and completion of the cast and wrought iron-work, in the several particulars hereinafter enumerated, for the whole of the bridges enumerated in the list accompanying this specification; the accurate fitting and proving the same; the delivery of the whole in a complete state, at such places as are herein specified; and fitting and fixing the same in place.

It will comprehend the following works, viz.:—

1. Providing the materials and casting the interior and exterior girders and beams of the forms and dimensions shown on the drawings, Nos.

1 and 2, to which more particular reference is hereinafter made, when the several bridges are enumerated to which each drawing is intended to apply.

2. Bearing plates to lay upon the timber plates and to receive the upper ends of the holding down bolts, as also bottom plates to be fitted on the lower ends of the same as shown in the drawing, No. 3.
3. Manufacturing and completing in wrought iron the tie bolts with couplings, cotters and washers complete, the holding down bolts, the king bolts for the principal girders, and the connecting bolts for the flange plates, with requisite nuts, washers and cotters.
4. The manufacturing, completing and fitting in wrought iron the segmental bars in the straight girders designed for bridges under the railway, with the requisite bolts and fastenings.
5. Also all other bolts and fastenings which may be thought requisite by the engineer for securing the timber or iron-work in any or the whole of the bridges hereinafter enumerated.
6. Fitting and fixing in place the whole of the iron-work, after being delivered, to be considered as "Extra Work," and to be paid for separately.

The preceding enumerated works, and the mode of execution, are described in the specification of each particular work, and their forms and dimensions are represented on the accompanying drawings, which are referred to in this specification; but should any discrepancy exist between the scale attached and the written dimensions, or between the drawings and specifications, or any ambiguity in them, the same are to be referred to the engineer-in-chief, whose decision shall be conclusive.

Also anything contained either in the drawings or specifications shall be equally binding upon the contractor, as if it were contained in both.

The written dimensions upon the drawings are to be taken in all cases in preference to the scale attached.

DRAWINGS.

The drawings are three in number, and are arranged for a general design; they show plans, elevations and sections of the several girders and beams, and of their principal parts and details. The only deviation from them now contemplated, will be the lengths of the exterior or principal girders, for skew bridges (depending on their angle of skew), and consequently the curvature of their upper and

lower ribs, the length of the king bolts, and the lengths of the beams bearing on them from the abutment walls.

The fitting and general construction will be the same, and deviations under this clause will be distinctly specified in the requisitions of the chief engineer, so as to leave no uncertainty as to precise form and dimensions.

PARTICULAR SPECIFICATIONS—CAST IRON.

Girders are to be of the best No. 2 iron, remelted in the air furnace with bright open round fractures of such a mixture most applicable for the purpose as shall be approved by the engineer; no hot blast iron is to be used. All the bolt holes to be drilled, except those for receiving the wrought iron bars for bracing or tying the girders together, which are to be cast to a proper size, and then bored out true to the size of the bar, so that it will fit and stand firmly in its position; each hole to have a boss cast round it sufficient to make up the difference of iron displaced by the holes.

No cement stopping or plugging to be introduced into a joint or cavity, unless first sanctioned by the engineer; and before the girders are delivered they shall be subject to be proved by hydraulic press, or otherwise by the contractor, under the inspection of the engineer, to such extent as the form and substance are calculated to bear, each girder not less than one half of the calculated breaking weights; this proof shall be made at the establishment of the contractor, and at the expense of the contractor.

The bearing plates are to be composed of the same metal as the girders above specified.

The whole of the castings shall be correctly moulded free from air holes, and shall measure their true dimensions when ready to be fitted in place.

WROUGHT IRON.

The segmental strutting bars for the straight girders designed for bridges under the railway, as well as all the bolts, shall be made from the best fagotted iron, or from any other equally good, if approved by the engineer in writing previous to manufacture.

The bolts for tying or connecting the girders to be made so as to fit the holes correctly, after the same are reamed to receive them.

The screwed ends of the bolts and the nuts to be cut with good screwing gear, and of such a mace as may be approved by the engineer.

The nuts and heads of the bolts to be well squared and of full dimensions; no nut to be screwed on the cast iron, but to have a washer under it, well proportioned as to thickness and diameter

PROGRESS OF THE WORKS AND DELIVERIES.

The deliveries shall be made at any one of the wharfs hereafter designated.

Requisitions shall be made upon the contractor by the chief engineer for all the iron-work hereinbefore specified which may be wanted.

Such requisitions in any one month shall not exceed in amount the quantity required for three bridges complete, commencing in the month of September next, besides holding down bolts and plates for the same, which shall be furnished upon requisition (as above) for not more than three additional bridges per month.

The contractor shall complete such requisitions and shall deliver the iron-work to the extent and in the manner they shall point out, within eight weeks after their transmission to him by post, for bridges, and within five weeks for holding down bolts.

The day of delivery shall be notified to the chief engineer at Worcester, in the same manner as prescribed in the Railway Company's Contract for rails and fastenings with James Foster, Esq., the contractor for the work herein specified, dated 14th April, 1838; and the consignments shall be made in the same manner that has been practised in the deliveries of rails, &c., to the resident assistant, or to the sub-engineer on the spot.

PLACES OF DELIVERY.

The following are the points at which deliveries are to be made on or before the dates respectively specified (see page 19) in the tabular enumeration of bridges appended hereto;—viz.:

Coombe Hill,	Defford,
Tewkesbury,	Kempsey,
Twining,	Lowesmoor Wharf, Worcester,
Bredons Norton,	Diggli's Wharf, Worcester,
Eckington,	Tibberton Wharf,

Oddingley Wharf,	Hopwood Wharf,
Oddingley Tramway Wharf,	King's Norton Wharf,
Hanbury Wharf,	Bredons Cross,
Stoke Prior Wharf,	Selly Oak Wharf,
Tardebigg Wharf,	Digbeth Wharf, Birmingham.

FIXING IN PLACE.

The contractor shall provide and furnish a sufficient number of artificers, under a competent foreman or overlooker, to fit and fix in place, in a complete and workmanlike manner, the whole of the iron-work provided for each bridge, within one week after notice in writing has been given by the chief engineer, specifying the particular bridge or bridges which are ready for such fitting to proceed.

The Railway Company shall provide sufficient materials, tackle and labourers to assist the above foreman, and to be under his directions; and the Railway Company shall be liable for the additional wages of such men so provided, during any period of delay caused by the works not being thoroughly ready, after the notice of the engineer shall have been acted upon by the contractor.

It is to be distinctly understood that the fixing in place is an " Extra Work," and is to be paid for agreeably with the " Second Schedule of Prices" hereunto annexed, and that the contractor is not to be at the expense of intermediate carriage from the wharf to the place of erection.

GENERAL STIPULATIONS.

The general regulations for the observance of the contractor are set forth in the printed form of " Conditions" at the commencement of this specification, and to them the contractor is referred.

Should it become necessary in the opinion of the engineer at any time during the progress of the works to increase, diminish, or alter the form or dimensions of any part of the work, the contractor shall comply with any order he may receive to that effect in writing from the engineer; the addition, diminution, or alteration to be allowed for according to the rates stated in the " Schedule of Prices" for the particular work annexed to the tender, and the general contract not being vitiated thereby.

The contractor is to provide all the necessary machinery and materials for the works during their progress, except those specified above for fixing.

Any materials which the engineer shall deem insufficient or improper to be used shall be removed from the ground by the contractor within three days after notice has been given him in writing to that effect; and in case of his failing to remove such materials in the time above specified, the engineer shall have the power to cause them to be removed by the most convenient means, and at the contractor's expense.

The whole of the work executed under the contractor is to be of the soundest description, done in a substantial and perfect manner.

In case of any question arising as to the weight of materials supplied, which cannot be conveniently determined by weighing on the spot, the weight computed from the drawings will be allowed; and no other weight will be admitted, unless an order in writing for the extra work or alterations or diminution, as the case may be, signed by the engineer and contractor is produced as a voucher.

LIST OF GIRDER BRIDGES

On the Birmingham and Gloucester Railway, to be provided with iron-work by contract with James Foster, Esq.

	Situations.	Over or under Railway.	Square or Skew.	Drawings to regulate dimensions.	Number of Girders required.						Estimated weight complete		DATE at which required.
					Fig. 1.	Fig. 2.	Fig. 7.	Fig. 8.	Fig. 9.	Fig. 10.	Cast Tons.	Wrot. lbs.	
5.6	Cheltenham	over	skew	1	2	23	—	—	—	—	64½	2714	30 September.
27	Cheltenham	do.	do.	1	2	6	—	—	—	—	22½	1349	
87	Cheltenham	do.	do.	1	2	19	—	—	—	—	55	1928	15 November.
75	Cheltenham	do.	do.	2	—	—	4	2	—	—	14	1032	
20	Besford	do.	do.	2	—	—	4	2	—	—	14	745	
61	Bredicot	do.	do.	1	2	19	—	—	—	—	55	1928	
45	Ashchurch	do.	do.	2	—	—	4	2	—	—	14	745	31 October.
12	Tredington	do.	square	2	—	—	4	2	—	—	14	745	
3	Ashchurch	do.	do.	2	—	—	4	2	—	—	14	745	
7	Defford	do.	do.	2	—	—	4	2	—	—	14	745	31 October.
12	Norton	do.	do.	2	—	—	4	2	—	—	14	745	
28	Cheltenham	under	skew	2	—	—	—	—	4	2	8	1203	31 October.
4	Swindon	do.	square	2	—	—	—	—	4	2	8½	1032	15 November.
32	Ashchurch	do.	do.	2	—	—	—	—	4	2	8½	1032	ditto.
4	Ashchurch	do.	do.	2	—	—	—	—	4	2	8½	1032	ditto.
9	Spetchley	do.	skew	2	—	—	—	—	4	2	8½	1032	
19	Himbleton	do.	do.	2	—	—	—	—	4	2	8½	1032	March 1839.
54	Hadsor	do.	square	2	—	—	—	—	4	2	8½	1032	ditto.
45	Hadsor	do.	do.	2	—	—	—	—	4	2	8½	1032	April 1839.
34	Hanbury	over	do.	2	—	—	4	2	—	—	14	745	January 1839.
60	Bromsgrove	under	skew	2	—	—	—	—	4	2	8½	1032	
26	Bromsgrove	do.	do.	2	—	—	—	—	4	2	8½	1032	
150	King's Norton	over	square	2	—	—	4	2	—	—	14	745	
1	King's Norton	under	skew	2	—	—	—	—	4	2	8½	1032	April 1839.
64	Bordsley	do.	do.	2	—	—	—	—	4	2	8½	1032	May 1839.
											424½	27,466	

The following Bridges will require particular Designs :

	Situations.	Over or under Railway.	Square or Skew.	Drawings to regulate dimensions.	Number of Girders required. Fig. 1.	Fig. 2.	Fig. 7.	Fig. 8.	Fig. 9.	Fig. 10.	Estimated weight complete Cast Tons.	Wrot. lbs.	DATE at which required.
14	Himbleton	under	square	—	—	—	—	—	—	—	8	1000	March 1839.
48	Hadsor	do.	do.	—	—	—	—	—	—	—	8	1000	April 1839.
29	Hanbury Canal	do.	skew 45°	—	—	—	—	—	—	—	60	2000	Span on square 24 ft., on skew 34 ft.
117	Stoke Prior	do.	do.	—	—	—	—	—	—	—	9	1100	November 1839.
95	Stoke Prior	do.	do.	—	—	—	—	—	—	—	9	1100	November 1839.
71	Stoke Prior	do.	square	—	—	—	—	—	—	—	8	1000	
9	Stoke Prior	do.	do.	—	—	—	—	—	—	—	8	1000	
109	King's Norton	over	skew	—	—	—	—	—	—	—	15	1000	
70	Bordsley	under	do.	—	—	—	—	—	—	—	5	300	May 1839.
60	Bordsley	do.	do.	—	—	—	—	—	—	—			
60	Bordsley	do.	do.	—	—	—	—	—	—	—	9	1000	May 1839.
					Approximate Estimate.						139	10,500	

SUMMARY.

456	Tons of Cast iron in beams, girders, and bearing plates,	at
107½	Ditto, ditto, in segment bars	at
17	Ditto of Wrought iron	at
		£6,420 18 4

AGREEMENT.

I, of

hereby agree and undertake to execute, according to the specification hereunto annexed, and subject to the conditions prescribed, the works on the Birmingham and Gloucester Railway, comprised in the contract for "Iron-works in Bridges," amounting by computation to

more or less, at the average price of

to be paid to me according to the "Schedule of Prices" for each particular work hereunto annexed.

Dated this day of 1838.

Accepted and agreed to

Directors of the Birmingham and Gloucester Railway Company.

(Signed) JAMES FOSTER.

BIRMINGHAM AND GLOUCESTER RAILWAY.

CONTRACT, No. 15, G.

Tewkesbury Depôt.

Specification of the several works to be performed in making and completing the depôt for the railway in the town of Tewkesbury, in the parish of Tewkesbury, in the county of Gloucester.

CONDITIONS ON WHICH CONTRACTS ARE TO BE MADE.

1. The contractor is to furnish all implements and tackle that may be required during the execution of the works. But it is understood that columns, girders, balustrades for office and entry stairs, grates, coppers, and stink traps are to be supplied to the contractor on the spot free of expense.

2. The contractor is to execute the whole of the works, as described in the specifications, to the satisfaction of the company's principal engineer and resident assistant engineer, who shall have power to reject materials which are not of the best quality, and to take down imperfect workmanship. The principal engineer is to decide disputes, if any arise; and the works are to be executed within the periods limited, either in whole or in successive portions, as stated in the specification.

3. The contractor to receive fortnightly 90 per cent. of the amount due for works performed. The balance to be retained by the company until after completion of his contract, under certificate of the engineer-in-chief, and to be then paid to him.

4. The work to be measured by the engineer, and the payment to be made by the company, through their secretary or pay clerk, upon the certificates of amount due, signed by the engineer-in-chief.

5. The copies of the specification, &c., and of the tender annexed, to be deposited with the resident assistant engineer. Contractor to have access to them.

6. In case of workmen employed or materials provided by contractor not being sufficient for completion of the works within the period named, contractor shall, upon notice from the company, provide such additional workmen or materials as the principal engineer shall deem necessary; and, in default, company shall employ such additional workmen or materials at the cost of the contractor, and may also deduct their wages and cost out of monies due to the contractor, so far as the same may be sufficient for that purpose; or it shall be at the option of the engineer, in case of such deficiency of progress, to foreclose the contract, on giving to the contractor a written notice days previously, to this effect. And if the contract is thus foreclosed, the contractor shall forfeit his claim to all monies or balance that may then be due to him, on account for it, by the Railway Company.

7. The company to have power to remove any persons in employ of contractor on the line, after notice thereof being given to the contractor.

8. The contractor is to deliver, at the office of the resident assistant engineer, or sub-assistant engineer, an account, every fortnight, of the number of artificers and other workmen employed the preceding fortnight, according to a form to be furnished, or to pay on default; also to deliver, at the same time and place, an acknowledgment, under the hand of the sub-contractor, or foreman, or overlookers, or head-workmen, that every person engaged by or under the contractor, has received the whole amount of his demand upon the contractor up to the date of such acknowledgment, or in case of any exception, to state the reason for such exception.

9. If temporary roads be necessary, engineer to set them out; contractor not to deviate therefrom.

10. The contractor to make satisfaction and compensation, as required by the Act, to all owners and occupiers, for damages by trespass of himself or his men.

11. The contractor not to make sub-contract without the consent of the company, except as to labour only.

12. Alterations or additions to works not to be executed without written authority, signed by the engineer-in-chief or resident engineer. Works admitted by the same authority to be deducted for, according to the scale established in the "Schedule of Prices."

13. The contractor, if required by the company, is to pay the sub-contractors and workmen their full wages (vouched as stated in Clause 8) on the day

to be appointed by the company, and in presence of the company's agent, in such places as the company may appoint, and no other. The same rule to apply to all payments made by sub-contractors, and company to have power of dismissal in case of non-compliance.

14. The contractor to employ no men on Sundays, except on such works as are certified in writing by the engineer-in-chief, or resident engineer, to be absolutely necessary. The company to have power to dismiss any man found so employed on Sundays, except under this certificate.

15. The contractor not to retail, either directly or indirectly, (without permission of directors) any article of consumption to the workmen.

EXTENT OF CONTRACT.

This contract comprises the formation and completion of several artificer's works hereinafter more particularly specified for the buildings, &c., according to the accompanying drawings.

The preceding enumerated works, and the mode of execution, are described in the specification of each particular work, and their forms and dimensions are represented on the accompanying drawings, which are referred to in this specification; but should any discrepancy exist between the scale attached and the written dimensions, or between the drawings and specifications, or any ambiguity in them, the same are to be referred to the engineer-in-chief, whose decision shall be conclusive.

Also anything contained either in the drawings or specifications shall be equally binding upon the contractor, as if it were contained in both.

The written dimensions upon the drawings are to be taken in all cases in preference to the scale.

GENERAL STIPULATIONS.

The general regulations for the observance of the contractor are set forth in the printed form of "Conditions" at the commencement of this specification, and to them the contractor is referred.

Should it become necessary in the opinion of the engineer at any time during

the progress of the works to increase, diminish, or alter the form or dimensions of any part of the work, the contractor shall comply with any order he may receive to that effect in writing from the engineer; the addition, diminution, or alteration to be allowed for according to the rates stated in the "Schedule of Prices" for the particular work annexed to the tender, and the general contract not being vitiated thereby.

The contractor is to provide all the necessary machinery and materials for thoroughly draining the works during their progress, whether by drifting, pumping, or other means. Also all planks, waggons, barrows, tools, and materials whatsoever for temporary ways that may be required in the execution of his contract; all of which are to be of a quality and construction approved by the engineer.

Any materials which the engineer shall deem insufficient or improper to be used shall be removed from the ground by the contractor within three days after notice has been given him in writing to that effect; and in case of his failing to remove such materials in the time above specified, the engineer shall have the power to cause them to be removed by the most convenient means, and at the contractor's expense.

The contractor will be held liable by the company for all damage to adjoining lands done by trespass of the people in his employ.

The whole of the work executed under the contractor is to be of the soundest description, done in a substantial and perfect manner.

The contractor will be at liberty to use the quantities of the several descriptions of work from which the engineer's estimates have been made, without the engineer being any further pledged for their accuracy.

In case of forclosure of the contract, the contractor shall forfeit all claim to the balance of monies, if any then due to him from the company, upon this contract.

Nett measurements only will be paid for, or allowed, without regard to any usage or custom to the contrary.

It is to be distinctly understood that the whole of the work executed under this contract is to be of the soundest and best description of each kind; and if any work of inferior description is introduced, which does not satisfy the engineer, it shall be rejected and not paid for.

PARTICULAR SPECIFICATIONS

Of the several works to be performed.

DIGGER OR EXCAVATOR

Is to excavate for the foundations of all walls that are to be built on new foundations, to level the ground and ram the same previous to commencing the footings, and to clear away all rubbish or material from the excavation according to the direction of the engineer; he is to excavate for the sewer or drain and cesspool shown on the drawings, and for all other drains or cesspools that may be required, and to clear out the wells if so ordered.

BRICKLAYER

Is to build all the walls of the several thicknesses and heights shown, leaving openings for doors, windows, &c., to the full dimensions figured on the drawings.

To build the several fire places, chimney jambs, breasts, backs, and shafts, with flues, 9 inches by 14 inches, properly gathered and pargetted, as shown on the drawings; the fire places to have each a strong iron chimney bar, $2\frac{1}{2}$ by $\frac{5}{8}$ths of an inch, with the ends turned up and down; the opening for fire places to be 3 feet high by their respective widths, and in the kitchen 4 feet high. As also all recesses, dwarf walls, piers, and retaining walls.

To dome over in 14 inch brick the wells now existing, with proper man holes, covered with forest landings and a strong iron ring; to build a 9 inch barrel drain to lead into the street sewer, forming a stink trap to former; to line in 9 inch brick the cesspool and water cisterns, and also a shaft for the water pump: to build proper stacks and spandrils for carrying the several flights of steps shown on the drawings; to build all privies and other conveniences, and generally to execute the whole of the brickwork requisite to carry out the design of the drawings, &c.; to turn 9 inch discharging arches over and under all openings, leaving a sufficient thickness for the face work.

The bricklayer is to cut all splays, rakes, and chasing, for lead flashings, and for stone or oak sills, and to make good where necessary; to form all reveals; to bed all plates, lintles and door and window frames, wooden bricks and bond timber; to do all wind pinnings and beam fitting.

The walls are to have the courses well flushed up, and they are to be carried

up in even and level courses throughout, in order to settle fairly. External faces to be worked with a flat ruled joint.

The bond shall be english or flemish at the option of the engineer. The walls shall be built solid with whole bricks, bedded full in mortar, with joints not exceeding $\frac{1}{4}$th of an inch thick, the bricks being previously thoroughly soaked in water, the whole being flushed solid, the joints pointed, and then grouted full.

The bricks to be used shall be sound and hard burnt; and where worked in on the face shall be of the very best severn bricks of uniform colour, and shall be thoroughly soaked in water before being worked in. The mortar shall only be used when fresh mixed; it shall consist of three parts of clean sharp river sand and one part of strong fresh burnt lime, thoroughly slacked and mixed dry with the sand, and then thoroughly tempered with a sufficient quantity of water.

EXTRA WORKS AT ORDER OF ENGINEER.

Cast iron stink traps to be fixed to all external apertures of drains.

To set all grates and coppers, also where walls are to be built on foundations.

MASON.

The front, in High-street, is intended to be faced with stone in the most substantial manner.

The stone shall be selected of the largest possible size, carefully chiselled and dressed to the different cheeks and mouldings shown on the drawings; no joint of mortar shall exceed $\frac{1}{8}$th of an inch thick, the beds shall be full and square for the whole depth of the stone, which in no case shall be less than 18 inches, and the joints squared back for not less than 18 inches; the courses shall be so selected in height as to suit in the best manner the several panels and mouldings.

All the arrises shall be carefully protected, so that when finished the work may be sharp and perfect. The parapets and chimney shafts above the roof shall in like manner be faced with stone, the coping being dowelled together.

The backing of brick shall be carried up at the same time as the facing and bonded into it, thorough stones being inserted at proper intervals, and at the gate-door and windows jambs in every alternate course.

The piers, to which the large entrance gates are hung, must be built solid, and the gate irons must be built in, sunk and run with lead; and forest blocks shall be used for the basement of the entire front. Forest stone landings, 6 inches thick, are to be laid over the tops of the two cross walls carried up in the middle of the

building from the ground; upon these landings the fire places and chimney breasts and shaft are intended to be carried up, as also the partition or cross wall between the rooms on the first floor.

Stone sills, 8 inches wide and 5 inches thick, weathered and throated, are to be provided and fixed to all the windows in the back fronts.

Forest stone steps, 12 inch treads and 6 inch risers, with rounded nosings, to be built under the entrance gateway, as shown on the drawings; the stones must be obtained of the greatest possible length, and the work must be of the most solid description.

The smaller flights of steps must in the same way be carefully and substantially built of the same material.

Large square forest stones, not less than 10 inches thick, must be fixed in the brick piers as bases to the iron columns, and as bearers for the iron girders.

Solid stone coping, not less than 4½ to 5 inches thick, showing 2 inches tomus on the outer edge in stone, not less than 3 feet long, dowelled together, must be laid on the retaining walls along the platform or stage, as also stone plancers, not less than 6 inches thick, along the ramp of the steps leading to the booking office, into which an iron railing will be sunk, the holes being cut for the balusters by the mason. Proper stone hearths, 18 inches longer than the width of the fire places, must be provided and fixed to all the fire places.

The fire places in the chambers to have plain stone mantle jambs, slips and shelves with rounded corners. Stone sinks shall be provided and fixed in the convenience and outhouse, with holes cut in them and large landings laid as pavement in a substantial manner to the privy entrance and area before it, as also to the back doors of the out buildings.

Stone imposts must be fixed to all arches exceeding 5 feet span.

PLUMBER, PAINTER AND GLAZIER

To lay all the lead gutters with 7lbs. rolled sheet lead, with 3 inch drips, to extend in all places 9 inches up the roof and 4 inches up the wall, with a lead flashing, 5lbs. to the foot, at least 5 inches deep; all the hips, vallies, and ridges to be laid with 5lb lead.

To provide and fix a pump with proper service pipes and all necessary stays and standards for the same.

To fix two rain water pumps with 2 inch suction pipes and 3½ inch cylinder, with oak standard plans, wrought iron lift and cheeks complete, using the old pumps for the purpose; if the old are rejected by the engineer as not fit, their price of providing new pumps to be extra.

To glaze with best Newcastle crown glass all windows and lights, to be well bedded and back puttied, and to make good all broken glass until the work is delivered over.

To stop, knot and paint in three coats of good oil colour all interior work usually painted, and all similar exterior work in four coats of oil.

PLASTERER.

Render, float and set kitchens, lath, plaster, float, and set fair for papering the living room and chambers, and for colouring or painting in the passages and offices.

Plain cornices, not exceeding 10 inch girth, are to be run in the chambers of the dwelling house.

The ceilings to be lath laid, and set in plaster.

SLATER.

To cover the whole of the buildings with duchess slates, nailed in two places with coper nails $2'' \times \frac{3}{4}$ deal sawn laths. Eaves to be laid double; the whole of the slates to have a sufficient overlap, not less than 3 inches, and to be carefully assorted in courses consisting of slates of equal thickness.

CARPENTER.

The whole of the timbers to be of the best sound yellow Memel, Dantzic or Riga fir, free from shakes or large loose or dead knots, and to be prepared according to the patentee's specification for Kyan's process.

No rafters, joists or quarters to be more than 12 inches apart in the clear, a tier of herring-bone struts, $2'' \times 2''$, in each room, on each of the floors. Provide and fix all necessary centreing to the arches and apertures, and support the same with proper struts and braces. Provide and fix 2 tier of bond timber in each of the stories, fir lintels, wall plates, and with wood bricks for the fixing of the joiner's work, as may be directed.

The bond and plates to be halved and dovetailed at the angles, and nailed and returned at the chimney breasts.

Lintels over all door and window openings to be $4\frac{1}{4}$ inches thick, and 18 inches longer than the width of the internal opening, and as wide as the walls will admit.

The roof, floors, and quarter partitions to be framed in a sound proper manner of the following scantlings :—

	Feet.		Inches.
Bond and wood bricks	4	×	$2\frac{1}{2}$
Wall plates on each story	$4\frac{1}{2}$	×	4
Joists of lodge and sitting room, ground floor	5	×	$2\frac{1}{2}$
English oak sleepers	4	×	4
Joists of one pair floor	10	×	3
Framed and trussed quarter partition head	6	×	4
Counter head	4	×	4
English oak, Queen's	6	×	4
Crown piece	$4\frac{1}{2}$	×	4
Strutts	4	×	4
Sills, quarters, braces, and puncheons	4	×	$2\frac{1}{4}$
Posts	4	×	4

Roof.

Rafters	7	×	3

Properly secured with iron foot straps and bolts to the tie beams, and securely nailed to the collar beams where they are used.

Tie beams	9	×	3
Collars	5	×	3
Ridge pieces and hips	9	×	$1\frac{1}{2}$
Pitching pieces	9	×	$1\frac{1}{2}$
Diagonal and Dragon pieces	$4\frac{1}{2}$	×	4
Trimmer to sky-lights	$4\frac{1}{2}$	×	4

Cover the whole of the roof with $\frac{3}{4}$ yellow deal rough boarding for slates, the edges shot with all proper tilting and springing fillets.

Privy.

Joists	10	×	3
Trimmers	10	×	$3\frac{1}{2}$

Fir proper door frames, 4 × 3, tenoned into stone sill, and $1\frac{1}{4}$ ledged and beaded door, hung with 12 cross garnets and screws and norfolk thumb latch, small bolt to same; $1\frac{1}{4}$ ploughed and tongued seat, with hole cut in same, and all

proper bearers; $\frac{1}{2}$ deal square skirting, 4 inches wide, round same; $1\frac{1}{2}$ deal ovolo sash hung on pivots.

Joiner.

The deals to be of the best seasoned Christiana or Stockholm.

Floors.

Lay $1\frac{1}{4}$ yellow deal floors (free of sap) to the rooms and passages on the one pair and ground floors, those on the ground floor, that are to be boarded, to be ploughed within $\frac{1}{4}$ of the bottom edge, and to be tongued with thin zinc.

Windows and Frames.

Deal cased frames, english oak sunk and weathered sills, $1\frac{3}{4}$ brass axle pullies, $1\frac{1}{2}$ deal ovolo sashes single hung, with best extra stout patent white lines and iron weights.

Those that are shown upon drawings with gothic heads, will have inch deal wrought and tongued linings or splays with backing, $\frac{7}{8}$ quirk moulding round same to all the windows, except the living rooms, which are to have $1\frac{1}{4}$ framed bead butt and square shutters, hung with $1\frac{1}{2}$ pair 3 butts and screws, with boxing to receive the same with single.

The window in the porter's room to be double hung.

Provide and fix square angle stafs, wherever required, at the chimney breasts, &c.

Doors.

The cellar doors to be $1\frac{1}{4}$ proper ledged doors, hung with 12 cross garnets, with oak proper door frames, 4×3, tenoned into stone sills, with 9 inch stock lock and norfolk thumb latch to same.

The doors under the spandrils of the stairs, opening on the platform for passengers, to be 2 inch panelled, as on the drawing, bead flush and square with gothic head and rabeted frame $4 \times 3\frac{1}{2}$, tenoned into stone sill and beded casing $4 \times \frac{1}{2}$, fixed round the jambs, soffet to the outside, hung with 4 inch butts, with 10 inch best iron rim knob locks, and 2—10 inch bright barrel bolts to same.

Similar doors to other openings on the ground floor, except the centre one, as shown in section, which is to have moulded transom and fanlight, as drawings.

Two inch moulded and square doors to the rooms on the one pair floor, the moulded side towards the passages with $1\frac{1}{4}$ deal single rebated jamb linings, with

dovetailed backings to each jamb, inch deal framed grounds, 4¼ wide, splayed at the back edge for plaster, and ⅞ moulding to same, hung with 4 inch Redmond's iron patent rising spring hinges, and 7⅝ inch mortice locks, with best knob furniture.

Skirtings.

Inch deal grooved skirting grounds to the booking office, passages, and sitting room on the one-pair floor, with deal moulded skirting, 9 inches wide, the angles to be properly tongued and housed.

Inch deal square skirtings, 7 inches wide, to the other rooms that are floored.

Staircase.

One and a quarter hard yellow deal nosed and 1 inch risers to stairs, with all proper brackets, carriages, &c.

One inch square bar balusters, 2 to each step, and 1 iron bar baluster upon every fourth step properly secured, 2 inch oak handrail to stairs, single moulded skirting on landings and stairs.

PROGRESS OF THE WORKS.

1. Up to the joists of the first floor throughout shall be laid by the 17th of November next.
2. Up to the wall plates throughout shall be laid by the 20th of December next.
3. The buildings shall be covered throughout by the 15th of January, 1839.
4. All the interior work shall be finished by the 28th February, 1839.

The advances, as per proposal annexed hereunto, shall be subject to 20 per cent. deducted, which 20 per cent. shall be paid on the subsequent fortnightly certificate of the engineer, provided that the above times have been duly observed; but this 20 per cent. shall be forfeited to the company, if the above times and amounts of work done have not been duly observed.

TENDER.

I, of

do hereby propose to make and erect the depôt in the town of Tewkesbury according to the plans and specifications exhibited to me; and to maintain the same until delivered over to the engineer, on completion of this contract; and to provide all the requisite materials within the periods, and upon the terms and conditions

mentioned and contained in the draft also exhibited to me, for the sum of *sixteen hundred and sixty pounds*—to be paid as follows, viz.: when the joists of the first floor throughout the building are laid £500; when the wall plates for the roof are laid throughout the building £300; when covered in throughout £200; when all interior work specified is finished £200: and the balance within one month after engineer's certificate of completion; allowance more or less being made, when the work actually performed, for any increase or diminution of work ordered as per clause 12 of the conditions hereunto annexed.

And I have in the "First Schedule," hereto annexed, set forth the prices of the different descriptions of work at which this tender is computed.

And I further propose to execute the several works in the said specification, denominated "Extra Works," at the prices affixed to each description of work in the "Second Schedule" hereto annexed.

And in case this tender shall be accepted, I hereby undertake to execute the agreement following to perform the works as above proposed, and under the conditions above referred to.

And lastly, I do hereby undertake and agree, that in case the said agreement shall not be executed by me within one week from the date hereof, the said company shall not (unless they think fit) be bound by this tender, but the same shall be absolutely void, in case the company shall so think fit; nor shall they in that case be liable to any claim by me in respect of work then already done by me upon the said railway.

Witness my hand this day of 1838.

To the Directors of the
Birmingham and Gloucester Railway.

(Signed) THOMAS P. HOLDER.

COPY OF A LETTER FROM THE CONTRACTOR TO THE ENGINEER-IN-CHIEF.

Sir,

Having examined the drawings along with you this morning, I find that the platform extends further than shown on the sketches from which I made my estimate of £1660, and that the additional quantity of work, both stone and brick, will amount to a further sum of £80, I beg to make my proposals subject to this increase for the Tewkesbury depôt.

Tewkesbury, October 11th, 1838.

(Signed) Thomas P. Holder.

ABSTRACT OF THE CONTRACTOR'S ESTIMATE.

Description of Work.	Super.		Solid.		Run.	
	feet.	inches.	rods.	feet.	feet.	inches.
BRICKLAYER.						
Brickwork in walls	-	-	47	187		
14 inch arches	565	6				
Cut splays in arches	152	6				
Cut quoins to do	-	-	-	-	65	0
Barrel drain	-	-	-	-	141	3
MASON.						
			15	0		
In plinths	-	-	151	4		
Moulded work on face	451	4				
Plain work on face	800	0				
Doors and windows	512	0				
3 inch landings	210½ sq. yds.					
2 inch hearths	37	6				
6 inch landings	10 yds.					
2 inch mantle and jambs	10	10				
Moulded steps	694	8				
18 inch coping	-	-	-	-	110	0
4 inch sill to privy	-	-	-	-	2	0
No. 3 plain chimney-pieces						
CARPENTER.						
Fir framed	-	-	553	10		
Ditto, in bond and lintels	-	-	171	0		
Ditto, in joists	-	-	233	2		
Gutter boards and bearers	385	3				
1¼ inch yellow deal floor	13½ sq.					
6 inch partition	2 sq. 65					
4 inch ditto	80 ft. 6					
¾ Rough boarded to roofs	14½sq.					
2 Panel square doors	82	4				
1½ inch partition	53	0				
4 Panel bead, both sides gothic head doors	97	6				
4 Panel square doors	60	0				
1½ inch proper ledged door	72	0				
Sash-doors	54	0				
Single rebated jamb linings	5	8				
Architrave linings	184	2				
Single moulding	-	-	-	-	51	0
Gothic fan-lights, No. 1						
Herringbone strutting	-	-	-	-	176	0
Deal cased frame oak sunk sills 1½ inch ovolo sashes, 1¾ brass axles, pullies, weights and lines, &c.	210	6				
Inch framed shutters	21					

Description of Work.	Super.		Solid.		Run.	
	feet.	inches.	rods.	feet.	feet.	inches.
Inch and quarter deal nosed treads and risers,	108	3				
square bar balusters	70	10				
Oak handrail	-	-	-	-	16	0
Iron bar baluster, inch square	-	-	-	-	18	0
4 inch square skirting	-	-	-	-	55	6
6 inch plain, ditto	-	-	-	-	56	6
9 inch moulded, ditto	-	-	-	-	281	0
Cut hole, and dished with cover to P., No. 1 .	189	0				
4 inched dresser top to corridor and drawers,						
handles, lock and key to dresser 2 . .						
Iron-rimmed knob locks, No. 12. . . .						
4 inch butts, No. 12 p						
Norfolk thumb latch, No. 7						
Woodstock locks, No. 6						
Cross garnets, No. 4, pair.						
6 inch bright bolts, No. 6						
Patent sash fastenings, No. 32						
SLATER.						
Duchess slates	15 sq.					
PLUMBER.						
Gutters and flashing lead	44 cwt.		80 lbs.			
Wall-hooks, No. 39						
Washer and waste in sink, No. 1 . . .						
2 inch lead pipe	-	-	-	-	18	0
Pump, with proper service-pipe complete, No. 1						
No. 2 rain-water pump suction pipes . .						
GLAZIER.						
Best Newcastle crown glass	208	0				
Skylight tops cut circular	11	0				
Fanlight over door, No. 1						
PAINTER.						
4 Oils	36½ yds.					
3 Oils	128 yds.					
4 Oils sashes and frames, No. 29						
Sash squares in 4 oils, 8 dozen and 4 . .						
Chimney-pieces, No. 4						
PLASTERER.	559 yds.					
Render, float and set to walls	66½ yds.					
Lath, plaster, float and set to partition . . .	270 yds.					
Laths lay set and white to ceilings, compo .	66½ yds.					
Plain corner, 10 inch girt	-	-	-	-	169	6

FIRST SCHEDULE REFERRED TO,

Containing a list of the prices of the several descriptions of work at which the accompanying tender is computed, the whole of the work being executed and completed agreeably with the foregoing specification :—

Excavator and Bricklayer.

Digging, per cubic yard . . . . .
Bricklaying, per rod of 272 feet . . . .
Barrel drains, per foot . . . . .
Brick flat in cellar floor, per yard superficial . .

Mason.

Cased and bonded stone front per foot superficial on the whole extent, opening included . . . .
6 in. forest landing, per foot superficial . . .
Weathered and throated sills, per foot run . . .
Forest treads and terrace steps . . . .
Ditto, risers ditto . . . . . .
Landings on platform forest thin, per superficial . .
Cube forest under columns . . . .
Blue stone hearths, per foot superficial . . .
Weathered coping, per cube . . . .
Forest border, sills, per foot superficial . . .
Stone jambs and mullions, per superficial . . .
Moulded coping, per run . . . . .
Ditto, cornice ditto . . . .

Carpenter.

Memel timber, per cube . . . . .
Ditto, in bond plates, lintels as per ditto . . .
Ditto, door-frames . . . . . .
Oak sleepers . . . . . .

Extra works.

Yellow deal ploughed and tongued floors with chains, per square
Ditto, staircases, per superficial . . . .
Ditto, boarding roof, per square . . . .
Ditto, gothic door head, per superficial . . .
Ditto, double-hung gothic head, per ditto . .
Deal cased frames oak sunk sills, $1\frac{1}{4}$ wide deal sashes, per super.

Ledged and beaded doors, per ditto . . . .
Angle staff beads, per run . . . . .
Moulded skirting, per run . . . . .
Beaded linings, per superficial . . . .
Jamb linings, per superficial . . . . .
Framed and beaded box shutters, per superficial . .
Skirting, per run . . . . . .
2 inch moulded sash door, per superficial . . .
Ditto, gothic headed, per ditto . . . . .
Wrought strings, per ditto . . . . .

SLATER AND PLASTERER.

Deal sawn lath for slating, per square . . .
Duchess slating, per square . . . . .
Plastering on walls, per yard . . . . .
Ditto, lath ceilings in plaster, per ditto . . .
Cornice plaster, per run . . . . .
Gothic arris, per ditto . . . . . .
Lath and plaster partition, 3 yards square . . .

PLUMBER, GLAZIER AND PAINTER.

Lead flashing, per cwt . . . . .
Ditto, gutters . . . .
Best Newcastle glass, per superficial . . . .

AGREEMENT.

I, of hereby agree and undertake to execute according to the specifications hereunto annexed, and subject to the conditions prescribed, the works on the Birmingham and Gloucester Railway, comprised in the contract *Tewkesbury depôt*, hereunto annexed, amounting to the sum of *one thousand seven hundred and forty pounds*, exclusive of "Extra Works" and alterations regularly ordered by the engineer, as contemplated in clause 12th of the conditions hereunto annexed, which are to be paid to me according to the "Schedule of Prices" for each particular work hereunto annexed.

Dated this day of 1838.

Accepted and agreed to { ______________
____

Directors of the Birmingham and Gloucester Railway Company.

(Signed) THOMAS P. HOLDER.

DETAILS OF THE

SWING BRIDGE, LONDON DOCKS.

H. R. PALMER, Esq., Engineer.

Plate 12.—Elevation and Transverse Sections of bridge, and Details of friction rollers.

Plate 13.—Longitudinal Section and Plan of bridge, showing framing.

Explanation of References on Plates.

a . . Iron post cased with steel, turned and polished.
b . . Iron socket cast hard in a metal mould and ground.
c . . The four adjusting screws.
d . . The inside of the ring turned true for the rollers to run in.
e . . The soil-plate cast solid.
f . . The arms having four adjusting screws.

The rack is secured to the tail of the bridge, and the projecting part is supported by a cast-iron bracket, screwed to external rib.

MANCHESTER AND BIRMINGHAM RAILWAY.

G. W. BUCK, Esq., Engineer.

Plate 14.—Plans, Elevations and Sections of the Stockport Viaduct, *(see Specification of same)*.
Plate 15.—Ditto, Details of Construction.
Plate 16.—Elevations, Sections and Details of the Cangleton Viaduct.

Specification for the erection of the Viaduct over the River Mersey, at Stockport.

The viaduct will be constructed of 22 semi-circular arches, each of 63 feet span; the particulars of which are exhibited in the drawings, and herein further described.

The whole of the foundations of the abutments and piers are to be laid upon the solid sand-stone rock. It is presumed that the rock will be met with at the respective depths shown in the drawings; and if otherwise, the foundations must be laid either higher or lower, as the case may require, in the judgment of the engineer.

The rock must be dressed off to a uniform level surface, equal in extent to the bottom course of the masonry of each foundation.

The contractors are to excavate all the foundations, to the depths shown in the drawing; to construct dams, to keep out or pump out the water, and provide all centreing-planks and tools of every description necessary to the perfect execution of the work, at their own expense, and to be included in the amount of their tender; and in case any of the foundations shall, in the opinion of the engineer, require to be laid lower than is shown in the drawings, the contractors are to make the required additional or other contingent works, incident thereto, at the rate specified in the second list of prices.

The increase of the excavation, masonry, or brick-work, or other matter constituting the foundation caused by such additional depth, will be paid for as additional work, at the rate specified in the second list of prices.

The earth, or other material, which it may be necessary to fill in round the brick-work or masonry of the foundations, must be well punned, pounded, or puddled-in, as the case may require, or as may be directed by the engineer; and the expense of performing it is to be borne by the contractors, and not to be charged as additional or extra work.

The value of such filling-in round the foundations of the piers and abutments, is to be included in the price for the excavations, where additional excavation is necessary, and to be included in the contract where additional excavation is not necessary.

The filling-in is to extend from the bottom of the foundation to the level of the surface of the ground. The surplus earth arising from the excavation of the foundations must be removed into the embankments surrounding the abutments, by and at the cost of the contractors.

BRICK.

The bricks to be made use of in the inside work shall be such as are known in Manchester by the name of "common bricks," of good quality, well shaped, and hard burnt.

The whole external face of the brick-work of the viaduct is to be built with second-stock bricks, of the best quality; and the whole depth or thickness of all the arches of the viaduct must be entirely built with the said second-stock bricks. In the arches the bricks must be laid by a line, and each brick firmly bedded with a mallet. No broken bricks shall be used, and no joint of mortar shall exceed a quarter of an inch in thickness. No difference of workmanship will be allowed in outside and inside work, except so far as herein specified; and the whole of the joints shall be flushed up solid with mortar, and the outside joint neatly drawn with a trowel, and struck with a straight edge.

The bond will be either English or Flemish, as the engineer may direct.

The contractors will not be allowed to build any of the outside work overhanded; but they must, in every case, lay it from the outside, and provide all scaffolding or stages necessary for the same.

The arches are to be backed with solid brick-work, up to the height shown in the drawing, and the spandrils are to be carried up with the backing to the

same height before the centres are eased; and the remaining or upper portion of the spandrils is not to be built until the centres are eased quite clear of the arches, and all the arches are turned and backed to the height shown in the drawing.

All the joints of the soffits of all the arches must be raked and neatly pointed.

After all the arches shall have been turned, and the centres eased or struck, and after so much time shall have elapsed as shall be sufficient, in the opinion of the engineer, to ensure no further subsidence of any of the arches, then, and not till then, shall the remaining portion of the spandril walls be built up to the level of the under side of the stone parapet.

No brick-work, or stone-work, to be set during frosty weather.

MORTAR.

The mortar to be made use of in the foundations in all those parts below the surface of the ground, in all the arches, and in the piers which stand in the River Mersey, to the height of the uppermost course of the stone-work of the base, must be laid in Artbury lime mortar, or in mortar made with hydraulic lime of equally good quality, such as shall be approved by the engineer.

The mortar to be used in the other parts of the work may be made with Burton lime, or any other lime such as shall be approved of by the engineer. The lime is to be mixed with clean sharp sand, in the proportion of three measures of sand to one of lime. The lime and sand must be intimately mixed and well tempered, by being ground together under edge-stones with a proper quantity of water.

STONE.

All the stone to be used in or for the viaduct, is to be stone of the best quality, from the Cloud Hill, or Runcorn Quarries; or other stone equally good, and approved of by the engineer.

The stone-work of the piers and abutments is to be of solid ashlar work throughout, from the foundations to the height shown in the drawings. Each course to be 2 feet thick. The outside courses to measure 2 feet 6 inches, and 4 feet alternately in the bed. No stone in the outside courses to be less than 4 feet long; and no stone, either in the inside or outside work, to break joint less than 18 inches.

The outside courses of the bases of the piers and abutments are to have 3 inch champered joints, with a tool-draft or margin 2 inches wide, and the remaining space pick-dressed. All the beds of the stones are to be accurately worked into true plane surfaces without any winde or hollow, and set with as close a joint as possible. Each course to be completed before the next is begun, and drafted and pick-dressed to a true horizontal bed.

The imposts are to be 3 feet thick, in two courses; and the stones of which they are composed are to measure 4 feet long in the face, and alternately 4 feet and 6 feet deep in the bed, exclusive of the projection; by this arrangement the long stones will break joint with each other two feet, and in each cross joint a 3 inch square joggle of hard stone, or of well burnt staffordshire brick earth, is to be inserted throughout the whole thickness of the impost (as shown in the drawing), and set in fluid roman cement of the best quality.

The imposts are to be moulded (as shown in the drawing), and their whole external surface fair tooled.

After the spandril walls shall have been built to the height shown in the drawings, then the stone parapet is to be erected (of the form and dimensions shown in the drawings). The whole of the internal and external surfaces of the parapet are to be fair tooled. No stone in the parapet to be less than 5 feet long. All the beds and cross-joints to be perfect planes, and set with close joints.

In each cross-joint of the parapet there must be a vertical joggle through the whole height or thickness of the course; and in each joggle a piece of hard stone, or of well burnt staffordshire brick earth, is to be inserted, 3 inches square, set in fluid roman cement of the best quality.

To carry off the water from the railway a 4 inch cast-iron pipe is to be built horizontally into the centre of each pier, and of each abutment, to discharge the water 1 foot above the level of the surface of the ground; the discharging end must project 4 inches beyond the face of the masonry, and be terminated with a $\frac{3}{4}$ of an inch bead, the inner end of each horizontal pipe must have a faucit joint, the bottom of which must be 6 inches above the upper surface of the horizontal pipe; the pipe is to have a quarter bend at this end; the faucit joint is to receive a 3 inch cast-iron pipe, which is to be built in the centre of each pier, and in each abutment, up to the level of the backing (as shown in the drawing).

The uppermost length of the 3 inch pipe is to finish in a cesspool made in a stone block, into which the water is to be brought by the drains (shown in the drawing.)

After any one of the arches shall have been turned and backed to the proper height, the arch and backing are to be coated with coal-tar, in the following manner, as soon as the weather will permit:—

The whole of the upper surfacc of the arch and backing must be freed from all dirt, dust, loose materials, or any other extraneous matter, by being thoroughly swept, or by other efficient means; and the work, after being thus cleaned, must be covered with coal-tar, prepared and put on in the following manner:—The coal-tar is to be boiled a sufficient length of time, to evaporate its water and ammoniacal liquor, to such an extent that when the remainder is suffered to cool it will set moderately hard, and without cracking: the requisite time for boiling is about ten or twelve hours.

The coal-tar, when thus prepared, is to be poured upon the brick-work by means of ladles or cans, and well rubbed into the surface of the brick-work with stiff brushes; and after the tar has been thus brushed into the surface and joints of the brick-work, another coat is to be poured upon it and suffered to cool thereon, to the thickness of, and not less than, a quarter of an inch.

After the erection of the spandril walls, they must be carefully coated with prepared tar, to the extent of 18 inches in height above the arch and backing; and great care must be taken to make perfect the connection between the coating of the arches and the spandrils.

The purport of the coating is to render the arches impervious to water; and it is proper to add, that the operation cannot be performed except in dry weather.

It is now known by experience, that when this work is well executed, the arches are rendered perfectly drop dry, and the contractor will be held responsible to make them so.

All the centreing must be constructed to the satisfaction of the engineer, for which purpose the contractor must lay before the engineer drawings of the centres which he purposes to make use of, and which must have the engineer's approval before the centres are constructed.

The contractor must commence turning the arches at one end of the viaduct, and proceed onwards to the other end; and he will not be allowed to remove or to ease any one centre until he shall have not fewer than eight arches turned, after which, the centre next the abutment may be removed, and be placed in advance, to serve the purpose of turning the next succeeding arch upon, and so on regularly in succession.

Provided nevertheless that the contractor shall not, in any case, be permitted to strike, remove, or ease a centre, without having the written permission of

the engineer-in-chief for that purpose; and if the contractor shall persist in acting in opposition to this provision of the specification, he shall be liable to the expense of all accidents or damages arising therefrom; and shall, in addition thereto, forfeit and pay to the company the sum of one thousand pounds for any violation thereof.

After the arches shall be turned back and coated, and the spandril walls shall have been carried to the proper height for the parapet, the contractor must fill the spaces between the arches, and also cover the whole of the arches with sand, up to the height of 1 foot above the level of the tops of the arches.

This must be done from one end of the viaduct to the other, and embrace the whole breadth between the parapets. The contractor will be required to fix as many vertical earthen drain-pipes in the ballasting between the arches as the engineer may direct.

These pipes will be furnished by the railway company.

PARIS AND VERSAILLES RAILWAY.

M. PERDONNET, Engineer.

Plate 17.—Plan, Elevation and Details of the Viaduct across the Vale of Fleury.

This design, it is presumed, will be reviewed with particular interest, as it contains some deviations from the usual mode of construction adopted in this country.

GLASGOW, GREENOCK, AND PAISLEY RAILWAY.

JOSEPH LOCKE, Esq., Engineer.

Plate 18.—Plans, Elevations and Sections of the Bridge over the River Cart, at Paisley,* *(see Specification of same).*
Plate 19.—Bridge over South Croft Street, *(see Specification of same).*
Plate 20.—Plans, Elevations and Sections of the Bridge over Cook Street.
Plate 21.—Ditto, Details of Construction.
Plate 22.—Plans, Elevations and Sections of the Bridge over the Pallack and Govan railway.
Plate 23.—Ditto, Details of Construction.

Specification of Bridge for crossing the River Cart, at Paisley.

This bridge of one arch, for carrying the railway across the River Cart, shall be built according to the form and of the dimensions represented on the drawing.

The foundations of the abutments shall be laid at the depths shown on the drawing, and shall be 33 feet long and 23 feet 6 inches thick, stepping off in three courses (1 foot each) to 28 feet long and 18 feet 6 inches thick. From this point to the springing of the arch, being a height of 25 feet 10 inches, the face of the abutment shall be built perpendicular, while at the back the curve of the arch being carried to the foundation, the abutment will gradually decrease in thickness to the springing, where it shall be 6 feet 6 inches thick, and 28 feet long. The courses in the abutment shall be radiated in the same manner, and from the same centre as the arch stones—the face stones being set square and bounded at every alternate course to the radiated arch of the abutment, as shown on the drawing.

* A clause in the Act of Parliament for the railway required this bridge to span the river in one arch, and that the foundations shall be 10 feet below high water-mark. The cost of it amounted to about £4,000.

The foundation courses, and for 10 feet in height from the base, shall be set in water lime.

As the dimensions are written on the drawing, it will not be necessary to insert them here: the following, however, are the principles:—

The impost shall be 1 foot 6 inches thick, and shall project and be wrought into the torus form, shown on the drawing; the arch shall be 85 feet span at the impost, and the rise from the springing to the soffit must be 18 feet. The arch stones must be 3 feet deep at the crown, increasing in thickness to 5 feet at the springing; they shall be 18 inches thick at the under side, and not less than $3\frac{1}{2}$ feet long. The exterior ring of arch stones shall have a torus moulding course, 1 foot thick, dressed into the form shown on the drawing. The string course shall be 15 inches thick, 4 feet on the bed, with a projection of 2 feet. Each stone shall not be less than 3 feet long. It shall be throated or undercut for the drop.

The parapet shall be 4 feet high, consisting of a plinth course, 15 inches in depth, 1 foot 9 inches wide; and one course 2 feet deep, 1 foot 6 inches thick; and a coping 9 inches deep, and 1 foot 10 inches wide. No stone in the parapet shall be less than 3 feet long. The upper edges of the plinth shall be chamfered. Each stone in the parapet shall be doweled together with iron dowels run in with lead.

A layer of good puddle, 18 inches thick, shall be laid over the arch for the full width of the bridge.

For the abutments, no stone in the outside courses shall be less than 2 feet by 3 feet by 14 inches; and every joint shall be broken by at least 1 foot of overlap.

The interior work shall consist of stones in courses equal in thickness to those on the outside, and not less in their other dimensions than 2 feet by 2 feet. The arch stones shall not be less than 2 feet 6 inches deep; but every alternate course, where the thickening of the arch will admit of two of these sized stones, shall be of the full depth shown on the drawing.

The exterior of the abutments to the springing shall be rough rusticated, as shall also the quoins of the pilasters, with a cleanly dressed joint, showing a clear edge of $1\frac{1}{2}$ inch at the front. The pilasters, impost, spandrils, string course, parapet, coping and caps, shall be tool-dressed. The underside of the arch stones to be neat pick-dressed.

The bridge shall be built of the best freestone, free from beds, shivers, flaws, or iron bands. Every stone shall be truly squared, jointed, and bedded, for the full dimensions given. No pinning will be allowed.

The mortar shall be ground in a pug-mill; and each course, after having been set in mortar, shall be well grouted.

The spandrils and arch stones shall be dressed off for the space of 2 feet, to receive the string or cornice, which shall be worked into the form shown on the drawing.

The pilasters shall be dressed off for the space of 2 feet, to receive the blocks and bands, which shall be finished with a moulding, as shown on the drawing.

Each block shall be 3 feet on the bed, 1 foot 6 inches in depth, 9 inches wide, and shall project at the top 1 foot beyond the band, which shall be formed of stones between each block, 1 foot 6 inches deep, 1 foot three inches wide, and 2 feet on the bed.

Relieving arches shall be built in between the spandrils, of the form and dimensions shown on the drawing. The piers or sleeper walls shall be 1 foot 6 inches thick, and shall be properly bonded to the cross wall, which shall also be 1 foot 6 inches thick, and 17 feet 6 inches high, built from spandril to spandril, and properly bonded thereto. These walls may be either of brick or rubble. The arches shall be of brick, 9 inches thick (as shown on the drawing).

All proper centreing, piling, dams, &c., to be formed by the contractor.

Specification of Bridge for carrying the Railway over South Croft-street, in Paisley.

The cast-iron bridge represented in this drawing is intended to carry the railway over South Croft-street. It shall be built of the form and dimensions shown on the drawing. It will require to be built askew, the line of the railway making with that of the street an angle of about 17°.

The roadway arch shall be 15 feet wide on the square, and have 21 feet 4 inches in clear height, from the present surface of the street to the underside of the arch at its highest point. The side or footway arches shall be 5 feet wide on the square, and 16 feet 2 inches high.

The abutments shall be built of brick, with stone pilasters and quoins, 3 feet by 2 feet, which shall correspond in thickness with four or five courses of bricks.

The piers shall be of brick or of solid ashlar, with chamfered joints, showing a clear edge to the front. They shall be of rough rustic-work, with a plinth-course 2 feet deep, projecting 1½ inch. This course shall be tool-dressed.

Grooves shall be cut in the masonry for the flange of each rib, 9 inches deep and 3 inches wide.

The imposts, pilasters, coping, string course, and plinth, shall be of stone, neatly and truly dressed, in lengths not less than 3 feet.

The stones in the pilasters shall average 1 foot 6 inches thick, and shall be laid header and stretcher, and the quoins shall not be less than 18 inches on the bed.

The counterforts shall be built 3 feet wide and 4 feet deep, of brick or rubble, in the form shown on the drawing.

In the rubble work, stones of a large size, as large as a man can conveniently lift, shall be used, and every course shall be flushed up with scabblings and well grouted.

The footway arches shall be built of brick; and in order to finish the extreme angles of the face, a 3 inch flange must be cast on to the inside of the footway beams, on to which the bricks shall be bedded.

On the top of these arches, and in line with the ribs and counterforts, brick walls shall be built, 1 foot 2 inches wide on the square, and of the height and in the manner shown by the cross section of the abutment in the drawing. The strength of the counterforts, piers and abutments, together with the position of the bed-plate and rib, as let into the masonry, is also described thereon. The course of masonry for receiving the bed-plate, shall, at the springing of each beam, be 2 feet 6 inches in thickness and 3 feet on the bed; in other parts the skew-back and impost may be in two courses, they shall be properly bevelled to receive the bed-plate, which shall be firmly fixed therein. The bed-plate shall be cast in convenient lengths, 1 foot 9 inches wide, and 2 inches thick, and shall be provided with suitable recesses for receiving the ribs; the ends of each piece shall be provided with an overlap flange to bolt them together, and to the masonry.

The span of the arch on the skew is 35 feet 6 inches, with a rise of 7 feet 6 inches; and the roadway of this main arch is to be supported by six cast-iron ribs, of the dimensions shown on the drawing. If it be found inconvenient to cast the ribs in one piece, the contractor shall provide, at the end of the beams, flanges 1½ inch thick, for the full depth of the rib, which shall be strengthened by three brackets on each side; and the ends of the ribs shall be bolted together with eight bolts, 1¼ inch square; the face of this flange shall be chipped smooth for its whole depth, so as to bear the pressure equally, for which purpose it shall be provided with chipping pieces; a key-plate shall be provided for the outer ribs to cover the bolts.

The covering plates slhal be 6 feet long for the space between the roads; they shall be 5 feet long for the space between the rails, and 4 feet 9 inches for

the space between the rail and the outer rib. They shall be bolted together with five bolts, and to the ribs by bolts passing through the chair and oak bearer, as shown on the drawing.

The cornice shall be cast hollow, of the form shown on the drawing, 9 inches deep, and projecting 11 inches from the face of the rib; it shall be $\frac{3}{4}$ of an inch in thickness. The plinth plate shall form part of this casting, and shall be 8 inches above the cornice, with a top flange 4 inches wide. Upon the inside face of the cornice, at points 3 feet apart, sockets shall be cast to receive the fastening pins from each length of the iron railing. The socket holes shall be 2 inches by $1\frac{1}{2}$ inch inside, and $\frac{3}{4}$ of an inch thick; the socket shall have holes cast at the points shown on the drawing, to receive a key, which shall pass through a corresponding hole in the fastening pins of the railing. A covering-plate shall be screwed on at the back of the cornice, to form a plinth course to the roadway. The cornice shall have a flange at the bottom, which shall be bolted to the top web of the rib; and on the inside the bolts shall pass also through the covering plate, so as to tie them firmly together.

The ballusters shall be 3 feet 6 inches above the plinth, and shall be 2 inches by 1 inch and 5 inches apart, and finished off at the top and bottom, as shown on the drawing. The top rail shall be $1\frac{1}{2}$ inch by 3 inches.

The span of the footway arches shall be 19 feet 2 inches on the skew, with a rise of 2 feet 6 inches; the ribs shall be 1 foot 9 inches deep, 2 inches thick, and shall be cast of one length, of the form shown on the drawing. Four of these ribs will be required; namely, one for each face of the footway arches. The roadway over those parts of the footway arches, from the face to the first spandrel wall, shall be covered with oak planks, 4 inches thick, as shown on the plan at B. The remaining space over these arches shall be filled in with ballast to the level of the roadway.

The bolts for connecting the ribs, roadway, and cornice-plate, shall be made of the best wrought iron, 1 inch square, and provided with proper washers.

All the ribs and plates shall be cast perfectly sound, from the second melting of metal, either from the cupola or air furnace; and each rib shall be tested with a load of forty tons, applied uniformly along its whole length before leaving the works.

All the joints of the plates shall be made good with gaskin, well saturated in the best tar, and filled up with iron borings, mixed to a proper consistency with sulphur and sal ammoniac, so as to make the whole impervious to water. The external part of the iron-work shall have three coats of good mineral paint, the colour of which will be fixed upon by the engineer at the time.

LEEDS AND SELBY RAILWAY.

JAMES WALKER, Esq., Engineer.

Plate 24.—Plans, Elevations and Sections of the "Accommodation Bridge," built for Shippen Farm.

Plate 25.—Ditto, ditto, Details of Construction.

This bridge is distinguished for its lightness of construction, there being no immoderate use of metal, as is frequently the case in cast-iron bridges.

BRIDGE OVER THE CLYDE, AT MILTON.

GEO. BUCHANAN, Esq., Engineer.

Plate 26.—Plans, Elevations and Sections of the Bridge over the Clyde, at Milton, *(see Specification)*.

Specification for building a Bridge over the Clyde, at Milton.

The south side of the bridge to run in a line between the north-west corner of the old mill, marked A on the plan, No. 1; and at point B, 79 feet from the east angle of the Duke of Hamilton's mill at C (the distance being taken square with the proposed direction of the bridge,) and thence continued in the same straight line. The north side to run parallel with the south side, and 14 feet distant, that being the intended breadth of the bridge, including the outside walls.

The bridge to consist of three semi-circular arches, each 47 feet span and 14 feet across the soffit. The face of the north abutment pier above the offsets to be about 23 feet from the corner of the old mill, at A, and exactly as marked off by the engineer, in presence of the two contractors; and the distance of the other piers to be determined from this. The foundation of the south abutment to be excavated 6 feet below the level of the springing of the arches, and also the rock between that and the middle pier (as shown in the elevation,) and the materials taken to fill up the space between the wing walls, or in building any of the rubble, if it shall be thought fit for it.

The body of each of the middle piers to be 8 feet thick and 14 feet long, exclusive of the cutwaters on each end, which are to project 5 feet in the middle, and to consist of segments of circles, tangents to the extremity of the pier on each side.

The abutment piers to be each 7 feet thick and 14 feet long, to be rounded off, and terminated at each end with a quadrant of a circle $2\frac{1}{2}$ feet radius, pro-

longed into a straight line running 18 inches parallel with the direction of the bridge, and terminating in the pilaster which projects 8 inches, and is 3 feet 4 inches broad, beyond which the wing wall commences. The pilaster rises perpendicular up to the springing, and then batters in a regular sweep along with the wing walls; the inside of the pier is prolonged into the wing walls and middle abutment wall; the corners at D and E next the wing walls, in plan No. 2, to be rounded off, as shown.

The wing walls on the south end of the bridge to run from the extremity of the abutment pier in the arch, of a circle 40 feet radius, setting off a tangent to the direction of the bridge, and extending 15 feet along the circle; to be then continued 30 feet further in the arch of another circle 65 feet radius, and touching the former at the point where they meet, the walls terminating in a point 40 feet from the inside of the pier, measuring along the direction of the bridge, and 24 feet from the line of the outside wall. The wing walls on the north side to run in the same manner, but to terminate in a point 50 feet from the inside of the pier, in the direction of the bridge, and 40 feet from the line of the outside walls; the radius of the circle being 45 and 70 feet respectively.

The wing walls, where they commence at the extremity of the bridge, to batter with a regular curve from the foundation to the top, where they stand on a line with the outside walls of the bridge, and this batter to diminish gradually till it terminates at about half the distance where the wall is carried straight up. The walls where they commence to be raised to a level with the roadway which is on the same level with the top of the cornice; to be continued at this level 15 feet, and then as they recede from the roadway, to diminish in such a manner that there be in every part a slope of 1½ foot horizontal to 1 foot perpendicular, from the side of the roadway to the top of the wall; the roadway being 25 feet wide.

Raise a sufficient iron railing on the level part, on the top of the wall next the bridge, extending 15 feet from the extremity of the parapet where it declines, and terminates in the arch of a circle. The foundation of the wing walls at the said commencement to be 4 feet thick, and to diminish gradually to 18 inches at its extremity. At the top under the coping it is to be 2 feet thick, and the coping to be 12 inches high, and to project 3 inches on each side. Each wall to terminate in a square pillar, projecting where it appears 3 inches all round, and the coping also to project 3 inches.

The middle abutment wall to be 3 feet thick at the bridge, to be raised to a level with the covers on the spandrel walls, and to diminish gradually in the arch of a circle, 45 feet radius, till it be 4 feet high.

where it terminates in a pillar 4 feet square; the upper course to form a cope of 12 inches thick, and projecting 3 inches on each side. In the middle piers, the coping under the springing of the arches to project 12 inches at the extreme points below this, and including the space for the moulding to be 12 inches thick; and above it on the top of the cutwater to rise 2 feet at the pilasters, and to be rounded to two spheres of 13 feet radius, and intersecting each other above the middle of the cutwaters.

The piers below the coping to be 8 feet thick for 12 feet, to be then enlarged by three offsets, each 6 inches broad and 12 inches thick, and below that is the foundation course of the same breadth and thickness, with the last and sunk level into the rock as far as necessary. The abutment piers to have the same coping and moulding continued round as far as the wing walls; above, the cutwaters to be rounded off to a sphere 6½ feet radius above the curved part of the pier, and to a cylinder 6½ feet radius above the flat part, and both terminating in a flat at the pilaster. The arches to spring 1 inch within the body of the piers, so that the piers will be separated 2 inches more than the span of the arch.

The arches to be composed each of four ribs, running at equal distances between springing, and the intermediate spaces to be filled up with a course of covers 6 inches thick running between each rib. The two outside ribs to be 2 feet deep in the arch, and 2 feet broad across the soffit, and the mouldings cut out of them, as shown in the section. The two middle ribs to be 18 inches deep in the arch, and 20 inches broad across the soffit, and to have the under corners bevelled off and rounded, as in the section.

The stones in all the ribs to be from 2 feet to 15 inches thick, diminishing regularly from the springing to the crown, the covers to rest on the top of the middle ribs, and to meet in the centre; but at every 6 or 8 feet one of the stones to project above the covers 9 inches or more, and to be 12 inches broad, leaving 4 inches of a check on each side for receiving the ends of the covers. The side walls to be perpendicular from the outside ribs, and to rise 16 inches above them at the crown, and to be at an average 2 feet thick.

Above the wall a course to run, 12 inches thick, and to project 1 inch; above this the cornice, 12 inches deep, and above it the parapet walls, consisting of a base 12 inches high and 12 inches broad, a dado course 18 inches high and 10 inches thick, and a coping 12 inches high, and projecting, as shown in the section.

Above each abutment pier a pilaster is to rise behind the outside ribs, 3 feet 4 inches broad, projecting 8 inches from the side walls, and the projection

continued to the top of the parapet, with mouldings similar to the cornice, and running on the same level; also projections similar to those on the parapet, the stones in the pilaster to be 2 feet 8 inches thick at an average. Between the side walls, and directly over the two middle ribs, two spandrel walls to run parallel with the side walls to the crown of the arch, 2 feet thick, and rising to the level of the top of the arch stones at the crown; to be closed in at the top with covers, at least 8 inches thick, and of such a length as to meet in the middle of each wall, the covers to run across the crown of the arch uniting and resting on the ribs.

Above the piers the spandrel walls to be united by a cross wall rising above the middle of the pier, filling up the space between the opposite arches, and at the abutment piers uniting with the wing walls and middle abutment walls. Between the arches this wall to be 4 feet thick at the springing, and to increase as the arches recede to 8 feet, and to continue of this breadth to the top; and at the abutments to be 5 feet at the springing, to increase with the spreading of the arch to 7 feet, and to continue at this thickness to the top.

The masonry of the middle piers and abutment piers to be on the outside of ashlar, laid in courses, from 12 to 15 inches thick, well bedded in the best lime mortar, and pointed on the outside with roman cement; the outside stones to be all broached in the face with good broached work, and to be well squared, drafted, and scabelled, in the joints and beds, at least 6 inches within the face; to be laid with headers and stretchers alternately, the headers not less than $3\frac{1}{2}$ feet long, nor less than 18 inches or 2 feet broad; the stretchers not less than $2\frac{1}{2}$ feet, nor more than $4\frac{1}{2}$ feet in length, and not less than from 18 inches to 2 feet in the bed.

The stones of the interior packing to be of the same thickness as the ashlar, of as large materials as can be introduced, laid so as to bond well with each other, as well as with the outside stones, and each course to be grouted with lime, and to be levelled throughout before the succeeding one is laid on.

The arch stones of the outside ribs to be droved on the outside and mouldings. The remaining inside and under side broached, and the middle ribs to be broached throughout, where they appear projecting from under the covers; the covers to be hammer-dressed on the under side. The stones in all the ribs to be levelled in the joints towards the centre of the arch; the joints draughted throughout and well scabelled between the draughts, so as to form the joints as smooth and close as possible; the checks in the ribs, and the back of the middle ribs where the covers rest, to be also draughted and scabelled; the covers to be all levelled and dressed in the joints the same as the ribs; and all the covers

and ribs laid in the best lime mortar. The outside walls to be built in courses from 12 to 15 inches thick, well bonded together with headers and stretchers, and bedded in lime, to be broached in the face, and to be squared, draughted, and scabelled in the beds and joints 6 inches within the face.

The projecting course below the cornice to be droved and scabelled in the joints and beds at least 6 inches within the face. The stones in the cornice to be not less than $2\frac{1}{2}$ feet in breadth along the cornice, and not less than 3 feet in the wall. The space under them, and above the covers of the spandrel walls and crown of the arch, to be filled up with good rubble laid in lime; the joints and beds of the cornice course well squared and draughted, and scabelled at least 6 inches within the wall, and the outside and mouldings droved; the base of the parapet wall, and the coping, to be droved on the outside and inside; the dado course to be broached outside, and the inside to be broached similarly to the work now executing on the front wall of the house; the stones in the base to be not less than 3 feet in length, and the dado course and coping the same, and not less than 9 inches of regular band. The spandrel walls to be of good rubble, and of as large materials as possible, laid in courses, and well bedded in lime.

About 15 feet above the springing of the arches a course to be carried horizontally in each spandrel wall, between the ribs, consisting of stones 2 feet long, set on edge and well packed together, and butted against one of the projecting stones in each rib; the middle abutment wall to be of the same kind of work with the spandrels, the wing walls to be also of good coursed rubble, of large materials, and the outside neatly laid and pointed. The coping of the wing walls to be hammer-dressed on the outside and half way over the top. The covers above the spandrels to be well jointed and bedded in lime.

Above the covers a stratum of clay to be laid, 9 inches thick, well puddled and beat down to a smooth surface. Above this, the space for 18 inches to be filled up with shivers of stones, laid with a regular surface on the top, 3 inches higher in the middle than the sides. Lastly, above all, a coat of good road metal of whinstone, 8 inches thick, extending between the walls, the stones broke to 8 ounces weight each.

The space between the wing walls and abutment walls on each end of the bridge to be filled up with chippings of stones, as far as they can be procured, and the remainder at the top with earth; the roadway to be also continued by an embankment of earth, gravel, or stones, to the Glasgow and Lanark turnpike, on the south, and to the Milton approach on the north, and

running level as far as the termination of the wing walls, and then rising regularly to each road; at the junction with the turnpike the sides to be rounded off, as shown in the plan, No. 1.

The top of the embankment for the roadway to be every where 20 feet broad, and to be regularly formed and laid with metal, similar to the roadway in the bridge, 12 feet broad and 8 inches thick, and rising 3 inches in the centre.

The side slopes of the embankment beyond the wing walls to be $2\frac{1}{2}$ feet horizontal to 1 foot perpendicular.

(Signed) GEO. BUCHANAN

25th Feb 1830.

GRAND WESTERN CANAL.

JOSEPH GREEN, Esq., Civil Engineer.

Plate 27.—Plans, Elevations and Sections of a Swing Bridge over the Canal.

Plate 28.—Ditto, ditto, Details of Construction.

Bridges of this description afford a very ready means of communicating between the opposite sides of small canals, as they may be very speedily opened; the framing also being light, and equally balanced, causes it to turn freely upon the centre pivot, upon the application of a very small degree of force.

NEWCASTLE-UPON-TYNE AND NORTH SHIELDS RAILWAY

ROBERT NICHOLSON, Esq., Engineer.

Plate 29.—Plans, Elevations and Sections of the Bridge over the turnpike road to North Shields, *(see Specification.)*

Plate 30.—Ditto, ditto, Details of Construction.

The adoption of timber bridges on railways, instead of stone and brick, is now becoming very frequent; and they may be described as very well fitted for oblique crossings on account of their economy, and this bridge is a very good specimen of this style of construction.

Specification and description of work to be done in the erection of a bridge over the branch turnpike road from Percy Main, High Row, to North Shields, on the line of the Newcastle-upon-Tyne and North Shields Railway.

The masonry to consist of two stone abutments, and wing walls, having parapets and copings thereon. The carpentry of a timber arch, of two ribs, and a timber roadway; the span of the arch, in the direction of the line of railway, to be 52 feet 6 inches, clear of the abutments; and the breadth of roadway, clear of the ribs at right angles to the line of railway, to be 22 feet.

MASONRY.

All the stone to be used in this bridge to be of a strong and durable nature, similar to that from Byker Hill, or White House Quarries.

The lime mortar to be composed of the best stone lime, well burnt, and mixed with clean sharp sand, using not less than one cart load of clod lime to three cart loads of sand.

The iron cramps, dowels, &c., to be made from the very best scrap iron.

MANNER OF WORKMANSHIP.

Proper trenches for the foundations will be dug out by the Railway Company; but when once dug out, the contractor of the mason's work of the bridge to take out any earth that may afterwards fall into them; the contractor also to keep the foundations clear of water.

All the foundations to be built 2 footings in height each. The lowest footing to project 4 inches on each side beyond the one above it, and to be laid with large bedded stones, broached to an uniform thickness of 14 inches. The faces to be drafted, and left rough as from the quarry. The stones to be jointed perpendicularly, and bedded solid.

The second, or upper footing, to project the same as the lower footing, and to be built of the same description of masonry as hereafter described for the abutments.

The abutments to be 8 feet thick above the footings, to be built of solid ashlar work; in front, averaging 2 feet broad in the bed, and in courses from 14 to 18 inches in height, backed with good rubble masonry, carried up vertically behind to the top of the facia course. The acute angles of each abutment to be built of solid ashlar work, the whole height to the dotted lines, as shown on the plan of the abutment.

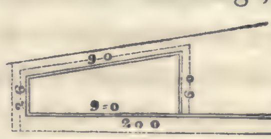
The buttresses to be carried up with, and properly bonded to, the abutments, and to be built of solid ashlar work.

The offsets, mouldings, and chamfers, to be worked agreeably to the plans, elevations, and sections, hereunto referred.

The wing walls to be 5 feet thick above the footings, and diminished by offsets to 4 feet at the top of the facia course. The faces to be ashlar work, averaging 16 inches thick, backed with good rubble masonry; the whole to be built in courses from 14 to 18 inches in height.

The facia course, parapet, coping pillars, and caps, to be of the several dimensions and descriptions shown on the drawings, and all solid ashlar work.

Wrought-iron bars, thus:— $2\frac{1}{2} \times \frac{3}{4}$ inches to be let in the stone-work at the acute angles of the abutments, with a bolt through the bar into each stone, thus, and a nut on the top. Five courses in each abutment, to the extent above shown, to be thus cramped, omitting each alternate course, and commencing from the top.



GENERAL DESCRIPTION OF MASONRY.

All the beds of the ashlar work to be broached; the joints to be squared back 12 inches from the face at least, and the face of all the ashlar work, excepting so much as will be hid by the embankment, (as per elevation), to be broached and drafted.

The faces of the abutments to batter, as shown on the drawings.

The stones to be set on their natural beds.

The ashlar work that will be covered by the embankment need not be broached on the face; but, with this exception, it must be similar to the other ashlar work.

The rubble masonry to be of the best description, and one-sixth of its contents to be thorough stones, to be joined to, and carried up with the ashlar work forming the front of the walls.

The parapet walls and pillars to be drafted and broached on both sides to an uniform thickness, and the coping and caps to be dowelled and cramped at the joints, thus,  and run with lead.

A seat for the wall-plate, 12 inches broad and 4 inches thick, to be cut in the masonry, along the top of the abutments, 1 foot from the face.

CONDITIONS.

The contractor to find all labour, lime, sand, stones, quarrying the same, leading, lead for dowels and cramps, machinery, planks, implements, materials, pumps, scaffolding, and every other thing necessary for commencing, carrying on, and completing the mason work; and in case it should be deemed advisable by the engineer to the Railway Company, for the time being, to make any alterations from the plans, sections, elevations, or details hereunto referred, (which said plans, sections, elevations, or details, are to be signed by the engineer, and the contractors for the masonry, to signify that they are the same referred to in the foregoing specification,) such alterations are not to vitiate the contract; but the addition to, or reduction from, the masonry which may arise from such alterations, in case of non-agreement between the contractor and engineer, shall be left to arbitration in the usual way.

All the iron-work specified with the preceding masonry is to be included in the tender for the masonry.

The masonry is to be wholly completed and finished within three months from the date of the Railway Company accepting the tender.

CARPENTRY.

Two longitudinal beams, $66\frac{1}{2}$ feet long each, to be laid across the opening on each side of the bridge, the ends of the beams resting on corbels 14 feet long each. The cast-metal saddles are to be set into these beams, and secured to them by bolts passing through both the beams and corbel; and the two segmental timber ribs, composed of three inch deals trenailed together, are to be fixed in these saddles, as shown in the plans.

The longitudinal beams are to be suspended from the arched ribs, and the whole trussed, framed, and strapped; as shown on the elevation, and according to the dimensions and scantlings marked.

The ends of the transverse joists are to rest upon the longitudinal timbers first described, and the ends to project 12 inches beyond the timbers; eight of the transverse joists, nearest the centre of the bridge, omitting each alternate joist, are to be trussed with a bar of iron $1\frac{1}{2}$ inch square, having three upright struts in the same, and the ends properly keyed on a metal plate 6 inches square and $\frac{1}{2}$ an inch thick, as shown in the transverse section.

The planking to be laid longitudinally across the transverse joists, and trenailed thereon.

Each side of the bridge to be closely boarded to the height of the top of the coping on the walls; the inside of the boards being flush with the inside of the parapet—the boards to be 1 inch thick, nailed to the framing and ribs.

MATERIALS.

All the timber to be from Memel, of the very best quality, and of such scantlings as are described in the drawings.

The deals forming the arched ribs, and the roadway, and all other deals, to be from Dantzic, of such lengths as may be required, and to be of the quality called "best middling," which is understood to be the best description of deals brought into the port of the Tyne. The whole of the timber and deals to be as free from sap, shakes, and loose knots, as possible.

All the trenails used in forming the arched ribs to be of English oak, or such other as may be approved of.

The iron straps, bolts, spikes, nails, and all other malleable iron-work, to be manufactured from the best scrap iron, or from iron of equal quality.

Each longitudinal beam to stretch between the abutments, and extend 7 feet upon each; to be 13 inches by 13 inches. Two beams in depth to be laid upon corbels, extending the same distance upon the abutments, and 7 feet from the face: these beams and corbles to be bolted together by $1\frac{1}{4}$ inch bolts, nuts, and screws. Two of the bolts at the end of each rib to pass through the cast-metal saddles. The beams to be laid to the gradient line of the railway, and proper mortices to be made in them for the insertion of the tenons of the upright posts of the trussing.

A wall-plate 43 feet long, 13 inches by 4 inches, to be laid along the top of each abutment, 12 inches from the face, and sunk its full depth into the masonry; the cross joists have to be laid upon, and spiked down to, this wall-plate, as hereafter described.

The joists of the roadway to be of the following scantling, viz., eight of the joists nearest the centre of the bridge, omitting each alternate joist, to be 13 inches by 13 inches, and the remainder 13 inches by $6\frac{1}{2}$ inches; the whole to be laid 3 feet apart, middle and middle, upon the longitudinal beams. The joists, 13 inches by 13 inches, to be trussed with a malleable iron bar $1\frac{1}{2}$ inch square, having upright struts resting upon the bar, of the dimensions, and affixed to the joists, in the manner shown in the drawings; the ends of the iron bar to be keyed upon a metal plate 6 inches square, and $\frac{3}{4}$ of an inch thick, resting upon the ends of the joists.

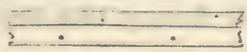
Ten $1\frac{1}{4}$ inch bolts (five at each side of the bridge) to pass through the smaller joists and the two longitudinal beams, to bolt the whole firmly together, and six of the other joists, viz., three at each side of the bridge, to be spiked down with iron spikes, 21 inches long and $\frac{3}{4}$ of an inch diameter, upon the longitudinal beams; the other ends of the joists being in each case spiked down upon the wall-plate by an iron spike 17 inches long by $\frac{3}{4}$ of an inch diameter.

The ends of the whole of the joists to be rounded off, as shown.

A horizontal deal strut, 13 inches by 3 inches, to be laid edgewise between each joist on the longitudinal beam, (as shown,) and secured with strong nails.

The two arched ribs are to be made to the proper radius, 1 foot 9 inches deep by 1 foot 6 inches broad, formed with Dantzic deals, 12 inches broad by 3 inches thick, laid flat, and dressed on the sides and edges, and of such lengths, varying from 20 feet to 50 feet long, as may best suit. The deal above to be bent over the one below, breaking the joint alternately both ways, and so that two end joints may never come fair over each other.

A layer of strong brown paper, laid on with the best Stockholm tar, to be put between each layer of deals.

The whole of the deals to be properly fixed together with the best oak trenails, placed 4 feet apart, thus,  ; each trenail to pass through three deals.

The upper side of the ribs to be weathered by a projecting deal on each side, sloped on the top, and a coping over and above.

The ends of the ribs, where they are fixed into the cast-iron abutment-plates, hereafter described, and the plates also, to have a good coating of tar.

Mortices are to be made in the under side of the ribs, for the insertion of the tenons of the upright posts of the trussing.

The abutment-plates to be 13 cwt. each, and of the description shown in the drawing; they are to be sunk their full depth into the longitudinal beams, and secured to them by two bolts $1\frac{1}{4}$ inch diameter, passing through both beams and corbels as shown; that portion of the plate which does not rest upon the beam is to be sunk into the masonry on each side, the same depth, and the whole of the plate to be firmly bedded on tar and oakum.

The ends of each rib are to be further secured to the longitudinal beams by an iron strap, 3 inches by $\frac{3}{4}$ of an inch, passing round the beams and ribs, and properly keyed, as shown in the drawings.

The timber for the trussing is all to be of the scantlings marked on the drawings. The upright posts are to be properly tenoned and fixed into the mortices of the longitudinal beams, and the arched ribs; they are also to be morticed for the reception of the tenons of the struts, and holed for the reception of the keys of the iron straps hereafter mentioned. These struts are to be of the scantlings marked, and tenoned into the upright posts; each alternate strut being tenoned into the opposite side of the centre of the posts, they will pass each other without reducing the scantling. The struts are to be bolted to each other when they pass, with five-eigths of an inch bolt, having proper nuts and screws.

An iron strap, 3 inches by $\frac{3}{4}$ of an inch, is to pass over the arched ribs at each upright post, and to be properly keyed through the posts on iron plates, as shown in the drawing; and a similar strap, keyed in the same way, is also to pass underneath the two longitudinal beams.

The planking is to be of 3-inch deals, of the quality before described, to be fixed to the joists by oak trenails, having two trenails in every deal at each joist; the planking to be laid down in such a manner that the ends may always break joints, and that two end-joints may never be opposite to each other, thus, 

The boarding for the sides of the bridge is to be of 1-inch deal; the inside of the boarding is to range flush with the inside of the parapet walls, and to be carried up to the height of the top of the parapet, and fixed to the framing of the bridge by double tack-nails, having two nails in each board where it passes every part of the framing.

All the timber for this bridge, after being cut into the proper scantlings, is to be led by the contractor to the Railway Company's tank-yard, on the line of railway near the Red Barns, Newcastle, where it will be put through a preparation for the prevention of rot, at the expense of the Railway Company: after being dried, it must be led away from the said tank-yard by the contractor, to the site of the bridge, free of all expense. The iron to be used in this bridge must be heated to about a blue heat, and the surface then struck over with raw linseed oil to prevent rust.

CONDITIONS.

The contractor to find all labour, wood, deals, iron, metal, cartage, machinery, tools, implements, scaffolding, centreing, planking, and every other thing whatever for commencing, carrying on, and completing the timber-work; and in case the engineer to the Railway Company for the time being, shall deem it advisable to make any alterations from the plans, sections, elevations, or detailed drawings, or in the construction of the timber or iron-work, which said plans, sections, and detailed drawings, are to be signed by the engineer to the Railway Company, and the contractors of the bridge, to signify that they are the same referred to in the preceding specification, such alterations shall not vitiate the contract; but the additional or decreased expense consequent upon such alterations as aforesaid, in case of non-agreement between the contractors and the Railway Company's engineer, shall be left to arbitration in the usual way.

All the malleable and cast-iron work specified with the carpentry, and all other iron-work, to be included in the tender for the carpentry.

The carpentry to be wholly completed and finished within one month from the time that the mason's work is in such a state of forwardness as to allow the carpentry to be commenced.

(Signed) ROBERT NICHOLSON,
Newcastle-upon-Tyne.

FORTH AND CART JUNCTION CANAL.

PLATE 31.—Plan and Longitudinal Section of Lock.
PLATE 32.—Ditto, Transverse Section and Elevation.

Explanation Letters of Reference worked on the Plate.

A. A. . . The side culverts, or puddle cloughs.
B. B. . . The overflow weirs.
C. C. . . The paddle frames.
D. D. . . The paddle wells.

PLATE 33.—Ditto, Plan and Elevation of Lock Gates.
PLATE 34.—Ditto, ditto, Details of Lock Gates.
PLATE 35.—Ditto, ditto, Details of Paddle, Rack, Pinion, &c.

(For Descriptions see Specification).

SPECIFICATION of sundry Artificer's Work required to be done, in cutting, completing, and making navigable the intended branch from the Forth and Clyde Canal to the River Clyde, opposite the River Cart.

This intended branch will commence at Whitecrook, near Mr. Black's house, and will proceed from thence in a straight line to the River Clyde, opposite to the River Cart. The line of proposed canal is marked out upon the ground; but the contractor must construct the several works according to the several drawings, and the specification. As the embankment between lock, No. 1, and lock, No. 2, has been increased in height since the ground was staked out, the ground required for the canal will consequently be wider than the space marked out upon the site.

With respect to the several lengths and heights, marked and figured upon the plan and section, the contractor must satisfy himself of their accuracy, as no claim will be allowed for extra work on account of any inaccuracy that may appear upon the drawings.

GENERAL CONDITIONS.

The following conditions and observations are to be strictly attended to by the different parties tendering for the execution of the proposed work:—

The whole of the materials provided are to be the best in quality of their respective kinds, sound, and well seasoned, and to be applied in the most substantial manner, under the direction and to the entire satisfaction of John Macneill, C.E., and the resident engineer appointed to superintend the works.

The drawings are to be equally binding with the specification; and should any thing appear to have been omitted in either or both, which is usually considered necessary for the completing of the several works, the contractor is to execute the same as if it had been particularly described, and is not to obtain any advantage whatever from such omission, but shall apply what may be wanting to complete the whole, and the works are to be left in a complete state, according to the true intent and meaning of the drawings and specification; and the directions for their correct performance, as given from time to time by the resident engineer, are in all cases to be strictly attended to.

The whole of the stone, timber, iron, and other materials, are to be delivered on the premises, and to be examined by the resident engineer previous to their being worked or used.

It shall be in the power of the resident engineer to reject any part of the materials which he may consider unfit for the work, and cause any part of the work to be altered which, in his opinion, is unsound or unworkmanlike, and not according to the contract, upon three days' notice having been given in writing for that purpose by the resident engineer; and in case the contractor shall refuse, or delay to rectify, or comply with the orders that may be given to him in writing, and shall perform all or any part of the work in an improper manner; or in case the works do not proceed with proper dispatch, the resident engineer shall have power and be at full liberty to suspend the further execution of the works by the said contractor, to take it out of his hands and employ or engage any other person or persons to perform or execute, and to find proper materials for the same, in which case all the costs and charges thereof shall be paid or

allowed to the Forth and Clyde Junction Canal Company, by the contractor or his sureties, or allowed or deducted out of the monies which may be then or become due to the said contractor, the amount of which shall be valued and decided by the engineer, whose award in this and all other cases respecting the works shall be final and binding.

It is also to be in the power of the engineer to direct such alterations to be made in the work during its progress as may be found expedient, which alterations shall not vacate or make void the contract, but shall be performed by the contractor according to the directions he may receive; and the value of the same, whether an addition or a deduction, shall be ascertained by the engineer, and be added to or deducted from the amount of such contract, according to the rate at which such work was undertaken; the award of the engineer, in such case, to be final and binding.

No allowance will be made to the contractor for extra or additional work unless the same shall be ordered, in writing, by the engineer, and unless a correct account or voucher of the said work is delivered to the engineer within three days of its performance.

The contractor to provide himself with all manner of labour tools, moulds, implements, scaffolding, centreing planks, ropes, ladders, hoisting tackle, and materials of every description; carriage, freightage, and every requisite for the completion of the works: he is also to make good any damage done by his workmen to any part of the works, through carelessness or otherwise; likewise to clear away all rubbish or waste that may arise, when desired to do so by the resident engineer.

To excavate for the foundations of all locks, bridges, culverts, as well as the other necessary works for the proposed canal, keeping out the water by placing dams, if required, &c.

Should it be deemed necessary at any time to suspend the progress of the works on account of the weather, or any other cause, the engineer shall be at full liberty to do so, and no extra charge shall be made on this account by the contractor.

The resident engineer to be at full liberty to order the discharge of, or dismiss from the works, any man or men for incompetency or misconduct; and the contractor shall not replace them without the written approbation of the resident engineer.

Should any of the materials be lost or stolen from the premises, no allowance can be made for the same.

The works shall be begun as soon as the contracts are signed, and the whole completed within under the penalty of
for the non-fulfilment of same, to be recovered as liquidated damages in any of Her Majesty's courts of law. In case of extra works, additional time will be allowed for same.

To deliver in a paper containing a copy of the estimate, with the quantities and prices upon which such estimate was founded, in order to show that it is a *boná fide* calculation, the same to be left with the engineer, in order that he may be enabled to value any additions or deductions that may arise, according to the prices of such estimate.

The contractor must enter into a bond, with two proper and approved sureties, for the performance of his contract.

The contractor will receive payments, upon producing a certificate from the engineer.

The contractor will have to keep the canal and works in proper repair and order for the space of twelve months after the completion of the same.

To keep an experienced foreman on the works, who is to be approved of by the resident engineer.

CUTTINGS AND EMBANKMENTS, AND FORMATION OF CANAL.

The extent of the several cuttings and embankments is shown upon the plan and section: the line shaded red represents the natural surface of the ground; and the space enclosed, and coloured blue, represents the proposed canal branch.

The slopes of both cuttings and embankments, except where otherwise described, will be 2 to 1—that is to say, when the height is 2 feet its base shall be 4 feet. The width of the canal being 40 feet, and a towing-path of 10 feet on each side, will give a base throughout of 60 feet, except at the open cut into the River Clyde, and the space between the stone bridge over the road from Glasgow to Dumbarton, and lock, No. 3, where the base will be 34 feet, also except at the locks generally.

The embankments to be carried forward as near the finished heights and widths as the due allowance for shrinking will admit of.

Great care must be taken to prevent water settling upon the embankments and cuttings during the progress of execution.

In the event of any springs or streams of water appearing from the face of the slopes, or otherwise, the contractor will be required to make such drains or water-courses as shall completely and effectually prevent such springs or streams from injuring the slopes during the progress of the works, and shall convey the whole of such water into proper drains.

The contractor shall also open or make any new drains, which the engineer may direct, for the exclusion of any water.

The space between the River Clyde and lock, No. 1, to be properly excavated, to a slope of 2 to 1; the whole of these slopes and tops of same banked up with, and to have a covering of rubble stone pitching, similar to the banks of the Clyde.

Dig for, and fill in, a good vertical puddle to same, 2 feet at top and 3 feet at bottom, to go at least 1 foot beneath the bottom of cut. Include 100 yards run of side and bottom puddle lining, as shown upon drawing, 1 foot thick, properly protected by suitable materials (as gravel, 6 inches thick) next the lock, or equal to the same in depth.

The circular ends to canal next the river must be pitched, 2 feet thick, with rubble stone, properly bonded together, and well backed up.

On the spots marked upon plan carry up circular dolphins, or water-marks, 7 feet diameter, and 3 feet above the flood tides, to be of hewn stone, domed over at top similar to the water-marks upon the banks of the Clyde.

The canal will be formed in embankment between lock, No. 1, and lock, No. 2, where it will be 7 feet 6 inches deep, with double towing-paths, and executed as shown upon drawing. The slope of water banks for canal to be 1½ to 1, all the rest 2 to 1.

The whole of the embankment will be made with side and bottom puddle lining, 2 feet thick; the upper towing-paths will have a lining of puddle, 2 feet thick.

Form a ditch upon each side of embankment, properly laid to a current, and having all the water-courses directed to same; the size to be 4 feet at the top by 2 feet at the bottom, and 1 foot 6 inches deep.

The cutting between lock, No. 2, and lock, No. 3, to be as shown upon the drawings, and to be executed entirely with vertical puddles, except where otherwise described. There will be a ditch, the high side of ground, 1 foot 6 inches deep, 3 feet at the top and 2 feet at the bottom, at the largest part, having the several water-courses properly diverted into the same: there will also be a small ditch on the other side of the cutting.

The remaining portion of the canal will be formed in a similar manner.

One-third of the deepest part of the line is intended to have side and bottom puddle linings, and the remainder vertical; the remaining portion of side and bottom puddle lining provided for as above stated, will be used in this embankment. There will be small ditches, as before described, to the embankment; and large ditto, as before described, to the cutting.

SOILING OF THE SLOPES.

The outside slopes of the banks to be neatly dressed to the required slopes, and soiled over with at least 6 inches of good vegetable soil, which is to be saved for that purpose: the slopes thus covered with vegetable soil are to be sown with good grass seeds, at the proper season.

APPROACHES TO STONE BRIDGE ON THE ROAD FROM GLASGOW TO DUMBARTON.

The rate of acclivity to the bridge to be 1 in 30.

The embankment of approach to be formed to a slope of 2 to 1, and similar to the other embankments upon the canal. The fence, and hedge and ditch, must be properly reinstated and re-planted.

There must be gates at each side of the road across the towing-path. The gates must have good Scotch oak 12-inch square posts, and five straight bars and two diagonal bars, $6'' \times 3''$, to be hung upon proper strong gate hinges, 2 feet 6 inches long, and proper spring catch and staple; the whole well painted, two coats, lead colour; the ends of the posts to be properly charred.

Four other gates, of this description, are to be provided for other parts of the line.

Previous to any of the works connected with the bridges being begun, a proper well-made temporary road shall be prepared and made; and in the case of the road before mentioned, it must be sufficient to afford a free and uninterrupted passage for carriages of all descriptions. Every caution being taken by the contractor, during the alteration, to erect proper fencing, and fix lights, as the Company will not be held liable for any injury which may ensue from neglect to these precautions.

The approach to the timber bridge over the towing-path of the Forth and Clyde Canal to be formed as before described, the acclivity of the road being in

the proportion of 4 to 1; and any extra stuff arising from the works to be given to this approach.

The general conditions to be as described to the stone bridge.

FORMATION OF ROAD FROM GLASGOW TO DUMBARTON.

Lay a coating of stones, 6 inches thick, over bridge and approach to bridge, properly spread and levelled; size of the stones about 2 inches diameter.

The traffic of the road shall then be allowed to proceed upon it until the works are completed, when a layer of fine stones, or gravel, shall be spread over the same, 6 inches thick, due allowance being made for the sinking and compression of the materials.

This metaling to be continued the whole length of approach, and the footpath must be properly continued throughout.

TOWING-PATHS.

Towing-paths are to be 10 feet in width, and to be formed by first leveling the canal bank to a height of 6 inches above the surface of the water, and then turning the same, and forming the road in a similar manner as described, to the road, from Glasgow to Dumbarton: proper drains must be made to carry the water off from the tail of the cuttings, and where required, of stones and tiles, set in strong mortar.

FENCING, &c.

The towing-path and boundaries of the Company's premises generally to be fenced with larch, or Scotch oak, as drawing; the posts to be 6 inches square, 3 feet 6 inches out of the ground, and 2 feet 6 inches in the ground, and two rails, $6'' \times 3''$, of the same wood, to be properly morticed into the same, the posts to be 7 feet apart.

Quicks will be planted on the outside of the fences; the quicks to be three years old, strong and healthy, and nine planted in each lineal yard, in a suitable soil provided from the excavations.

A proper ditch must enclose the whole, as before described.

To provide whatever temporary fencing may be required during the execution of the works.

The whole of the fences, hedges, and ditches, also roads, and the like, that may be disturbed by the proposed works, to be properly reinstated, and connected to the new portions of the same.

Whatever stones, sand, and gravel, and whatever may be found in digging and opening the cut, is not to be sold or taken from the work, but to be used or deposited where the resident engineer may direct.

The puddles to be composed of good stiff clay and a small quantity of gravel, well mixed together, and the whole of it is to be laid in courses or layers, about 9 inches in width, the whole rendered thoroughly impervious, or water-tight.

The concrete used in the foundations, and where ordered, is to be mixed in the proportion of seven measures of gravel to one of ground lime, of approved quality; they are to be well mixed, by manual labour, after which a sufficient quantity of water is to be added and well mixed in; it is then to be pitched from barrows, from a height of at least 10 feet, in regular layers, and brought perfectly level.

LOCKS.

The locks to be constructed according to the several drawings.

The lock chambers to be 68 feet long, out and out, and 15 feet wide at the gates, and 17 feet in the centre of the lock at the coping.

A space of 33 feet is to be included on each side of the lock chamber (taken from each side of the gates, a width of 15 feet), and the embankment and cuttings to this space of ground to have slopes 2 to 1, similar to other embankments, and proper ditches and fencing.

The ground around lock, No. 1, will be laid out as shown upon drawing, having circular embankments ; the whole surface of terrace and embankment will be laid with puddle, 2 feet thick, and then properly metalled and ballasted, similar to the towing-path.

The ground around the other locks will likewise be metalled and ballasted.

A plot of ground next the road from Glasgow to Dumbarton is marked out on the site, for the lock-keeper's house, &c., which is to be fenced and ditched in a similar manner to the rest of the works.

After the requisite excavation is formed, the lock chamber, and counterforts,

to be carried up in good freestone, free from all flaws and defects, the whole laid in its natural or quarry bed, and of good even colour; the upper and lower breadth of every stone to carry its full thickness from front to back, so that the bearing, both above and below, may be perfectly square and level throughout. No pinning in levelling will be allowed; and each stone is to be brought firmly to its bed by a wooden mallet.

The walls to be carried up to the required curve and batters, in courses varying from 12 to 15 inches in thickness; the headers to be the whole thickness of wall, and the stretchers to be half the thickness of wall in width, to be laid one header to two stretchers, properly bonded, and breaking joint together.

The course of stone immediately under the coping to be laid all headers.

The top course of stone to wall, forming coping, to be good whinstone, 12 inches thick, and rounded on the top edge, and to be alternately about 1 foot 8 inches and 2 feet in width, and in long lengths, as shown upon drawing. The stones next the lock-gates to be in large sizes, the quoin-stones being 7 feet by 6 feet, as shown upon drawing; and the curb to lock-head will be of whinstone, 12 inches thick, and rounded on the top edge, and of the sizes shown upon the drawings.

The invert to be formed of freestone, as shown upon drawing, the centre course being 15 inches thick.

Carry up the paddle-wells and culverts the several thicknesses shown and figured on the drawing, the paddle-frame being properly let into the wall. Set whinstone coping round the same. The culvert will be quite unconnected with the wall of the chamber, and it will be laid with a slight fall.

Form waste weirs, or overflow drains, in masonry, from the upper level, into culverts, as shown upon drawings.

The wing walls to be carried up the several thicknesses and dimensions shown and figured upon drawings, with a winding batter; the counterfort to be plumb: cope the same with whinstone coping alternately 1 foot 7 inches and 1 foot 10 inches wide, and 12 inches thick.

The retaining walls next the lower level to extend 20 feet on each side of the lock chamber, to be carried up in freestone, with whinstone coping, 12 inches thick, of the several thicknesses shown and figured on drawing, with the required batter.

There will be a wall of freestone, 2 feet thick, with whinstone coping, 12 inches thick, at the lower entrance into the lock, to protect and support the bottom of the canal at this point. Fill in puddle, 2 feet thick, properly protected by gravel, between this wall and platform.

The whole of the walls and masonry above described will be backed with stiff puddle, 2 feet in thickness, where the foundation is not good; the ground must be laid with concrete, properly levelled, to receive the walls.

In all cases there must be bottom and side puddle lining to the bottom of the canal, to 10 feet beyond all wing walls.

The whole of the whinstone coping and curb to be well joggled together, by a groove in the centre of each joint, into which a whinstone block will be fixed, properly grouted with mortar, and worked with chisel-drafts round their faces, beds, and joints, and picked between the joints, so that, upon applying a ruler upon the face, no part shall be above them, and no more space than $\frac{1}{8}$th of an inch below them, the outside faces being marked with exact regularity and neatness.

The freestone is to be of the best description, and from Netherwood, Brighton, or Dobbie's Quarries, and to be fair dressed on the faces, backs, and joints.

The whole of the stones are to be worked on the ground, and set with lewises and proper tackle.

The whole of the stone-work throughout is to be laid on a thick bed of mortar, of the following description: one measure of good stone-lime, one measure of mine-dust, and one measure of sharp clear sand, free from rubbish, dirt, and other impurities. The mortar is to be well tempered and worked to a tough and proper consistency, and properly ground; and no more is to be made at one time than can be consumed in the day's work.

The lime is also to be brought in small quantities, and to be kept under an inclosed shed, so as not to be injured by exposure to the air or weather.

The lime is to be slacked, and mixed with mine-dust and sand; they are then to be pressed together in a dry state through screens, and the water added.

THE UPPER LOCK-GATES AND PLATFORM.

The gates to rest upon a proper timber platform, as shown and figured upon drawings, having No. 4 cross bearers, $12'' \times 9''$, resting upon plates, $10'' \times 5''$. Planking, 4 inches thick, will be laid down upon the cross bearers, and 3 inch planking laid in a diagonal direction upon the same: the clap cill, $14'' \times 12''$, and frame, $12'' \times 12''$, will also be laid upon the 4 inch planking: the frames will be strengthened by wrought-iron ties, $2\frac{1}{2}'' \times \frac{3}{4}''$, properly bolted to cross bearers and planking: there will be one tier of $2\frac{1}{2}$ sheet piling, 8 feet deep, to protect

platform. The whole of the timber above described to be of sound elm, and properly bolted and secured together.

		Ins. Ins.		Ins. Ins.	
The gates will have	top rails,	12×10,	at one end, and	11×10	at the other,
,,	bottom rails,	12×10,	ditto,	11×10	ditto,
,,	middle rails,	$10 \times 9\frac{1}{2}$,	ditto,	$10 \times 8\frac{1}{2}$	ditto,
,,	heel posts,	14×12			
,,	meeting posts,	11×11			
,,	planking,	$2\frac{1}{2}$			
,,	balance beams,	13×13,	ditto,	9×9	ditto,

having a moulded lining to the same, properly loaded.

There will be a foot-bridge attached to each gate, as shown upon drawing, having brackets, $5'' \times 4''$, upon which 2 inch planking is laid, 1 foot 9 inches wide, with hand-rail and posts, $3'' \times 3''$, to complete the whole, properly secured.

The whole of the above-mentioned timbers are to be of good sound oak, and to be properly morticed and tenoned into each other, and further stiffened by a wrought-iron stay at back, $2\frac{1}{2}'' \times \frac{3}{4}''$, continued the whole height of gate, and extending upon the rails, as shown upon drawing, properly bolted.

PIVOTS TO GATES.

The heel-posts of gates are to be secured by a hoop of wrought-iron, $\frac{3}{4}$ of an inch thick and $2\frac{1}{2}$ inches wide, laid on top; a 3 inch cast-iron pivot to be secured to the same, having a $7\frac{1}{2}$ inch shoulder, and a plug, $2\frac{1}{4}$ inches square, and let into the post 12 inches; a cast-iron socket-plate of $1\frac{1}{4}$ inch metal, the socket being $2\frac{1}{2}$ inches above the face of the plate, is to be prepared to receive pivot; the plate is to be let $1\frac{1}{2}$ inch into a stone carried up from the wall beneath the planking, being cut to fit the same.

GATE-ANCHORS AND COLLARS.

The gates to be secured to anchors by wrought-iron collars, 5 inches wide and $1\frac{1}{4}$ inch thick at the swing, and 3 inches wide and $1\frac{1}{2}$ inch thick at the ends, with 1 inch wrought keys to anchor, which is to be of wrought metal, the arms $1\frac{1}{2}$ inch wide, and let into stone coping $2\frac{1}{2}$ inches, and well run with lead; at the extremities of the latter will be cross pieces, let into stone 5 inches, and well run with lead; the cross piece, having eyes to receive the ends of collar,

will be 3 inches thick, and will stand up above face of coping 5 inches; a shoulder must be formed for the keys to pass through, as shown upon drawing; the anchors will be further secured by $\frac{3}{4}$ inch bolts, let into stone 12 inches, and well run with lead; a wrought-iron hoop will be dropped upon the top of post, which will be tenoned into the balance beams, and the latter will be tenoned into the mitre-posts, these posts having a $\frac{3}{4}$ inch wrought hoop of iron at both ends.

PADDLE AND FRAME, RACK, PINION, &c.

Build an oak frame, $9'' \times 9''$, in the masonry, for paddle, having a lintel and sill $9'' \times 9''$, projecting 12 inches beyond frame on each side, properly morticed for the same; there will be another cross timber, $9'' \times 9''$, tenoned into frame for paddle iron-frame. Line between the last timber and lintel, with 3 inch elm lining, well caulked and pitched, the framing being properly prepared for the same.

The paddle to be of cast metal, $1\frac{1}{2}$ inch thick, having 2 inch bordering on both sides, the bordering will be 1 inch thick; also cross bars, $\frac{1}{2}$ inch thick, to eye of paddle, as shown upon drawing.

The iron paddle-frame to be 1 inch thick on the face, which is 4 inches wide, the bottom rail excepted, which is but 2 inches wide, having studs, through which the bolts are passed; the return will be $\frac{1}{2}$ inch thick, and showing a face of $2\frac{3}{4}$ inches, it is let in flush with the oak frame $1\frac{1}{4}$ inch slides of cast metal, $2\frac{1}{3}$ inch on the face, having studs cast upon the same; $\frac{1}{2}$ inch bolts are passed through these studs and through the frames, and properly bolted; a $\frac{3}{4}$ inch cast metal stop is to be bolted on the bottom of frame, as shown on drawing.

The several joints in the paddle and frame must be made perfectly true and water-tight, by rubbing them together.

There is a wrough-iron rod, 1 inch diameter, attached to the paddle by the two eyes cast for the same, and secured by wrought keys, being properly shouldered at the upper eye, through which it is dropped square instead of circular, as the remaining portion; this rod is secured at the upper end to the rack, where it is again shouldered and let in square, and secured by a wrought key.

The rack is to be $3\frac{1}{2}$ inches on the face and $1\frac{1}{2}$ inch thick, having a fillet cast on the back, which runs on a friction roller to keep it straight; a groove will be left in the centre of front, $\frac{5}{8}$ inch wide, and the teeth will be reversed on each side of the same; the teeth will be 1 inch pitch, or from centre to centre.

The pinion to be $3\frac{1}{2}$ inches wide and 4 inches diameter, the teeth properly fitting into the rack with groove, &c.

The pivot is supported at each end by cast cheeks, 1 inch thick and $1\frac{1}{4}$ inch at the eye, having a $\frac{3}{4}$ inch wrought-iron spindle passed through the same, to which the handle, properly shouldered, is attached by a square socket; the cheeks are secured to the cap of the oak post, $6'' \times 6''$, by $\frac{1}{2}$ inch bolts and nuts, the capping of the post is $\frac{5}{8}$ of an inch, cast metal, as shown on drawing; the friction roller, 2 inches diameter, is allowed to run in sockets left for same in the back of the cap.

The well is covered at the top by a 3 inch proper ledged oak flap, in a rebated oak frame, $6'' \times 6''$, for which the coping must be properly prepared; the flap must have strong flap hinges, staple, asp, and strong padlock.

The gates must be made perfectly water-tight at the joints, by sand and water being worked through the hinge-joints; the mitre-joints to be made exactly true; the platform must also be well paid with tar, the joints being properly stopped, as the resident engineer may direct.

LOWER LOCK-GATES.

These gates will have rails, posts, and planking, and foot bridges similar to the other gates, and as before described.

Each gate will have a paddle at the bottom of same, the muntins of which will be $9'' \times 6''$.

The paddle must be similar to the other, and have a cast-iron frame complete, as before described.

The rack, pinion, &c., will also be similar.

The platform, also, will be of similar scantlings and descriptions, and according to the several drawings, except that there will be two tier of $2\frac{1}{4}$ inch sheet piling, 8 feet deep.

Fix, properly secured in chamber wall of lock No. 1, two fender-piles, 6 feet above coping, and 5 feet below it, to secure the lock-gates to when open; provide all proper chains and staples for same.

Build up solid with front retaining wall of the same lock, an oak step-ladder, having 2 inch treads 9 inches apart, and 6 inch sides, with the proper iron run and guide-ropes.

The retaining wall must be built to the required skew.

Provide eight oak mooring-posts, 2 feet out of the ground and 4 feet in it, to be fixed where directed.

STONE BRIDGE AT ROAD FROM GLASGOW TO DUMBARTON.

This bridge to be built of the several heights, widths, and thicknesses, shown and figured on the drawings.

The general description of the stone and materials, and also the method of working, to be similar to that described for the erection of the locks. The bridge will be built of freestone, in courses of about 12 inches wide; the coping and blocking courses forming the plinth of bridge upon the inside, to be of whinstone, worked as before described.

The wing walls will also be as those described for the locks, having puddle backing, &c.

The backing of arch, and the excavation formed in putting in the walls, to be filled up with concrete.

The bridge to be built to the required skew, to suit the direction of the road.

And the arch stones must likewise be built in spiral courses, to suit according to the skew.

TIMBER BRIDGE FOR THE TOWING-PATH OF FORTH AND CLYDE CANAL, AND WING RETAINING-WALLS.

The wing retaining-walls to be as described, to the lock wing-wall, with whinstone coping, &c.

The timber for bridge to be Memel, Riga, or Dantzic, free from flaws and defects.

Throw over two beams, $12'' \times 6''$, as shown, well struted by struts, $12'' \times 6''$, notched into beams, upon which the handrail and posts, $6'' \times 4''$, will rest; wrought-iron straps and bottom plates, $2'' \times \frac{5}{8}''$, with nuts and screws complete, must be provided to tie the whole together, as shown on drawing. The centre tie-iron will be 2 inches square, to which the heads and shoes will be secured by wrought pins; the posts at each end of the longest truss will be secured on the outside of same, by $\frac{3}{4}$ inch screw-bolts.

Two good stiff struts, $6'' \times 4''$, will be bolted to hand-rail at each end, well footed at their extremities. Lay upon beams 4 inch planking, properly fastened to same.

The beams will lay upon Scotch oak plates, $12'' \times 9''$, and the struts upon

Scotch oak plates, 9″ by 6″, properly let in flush with wall, and extending over 4 feet on each side of bridge.

This bridge must also be built to the required skew, which will also regulate the situation of the wing-walls.

CULVERTS.

The culverts must be built to the necessary angle, according to the situation, and each culvert is to be placed so as to afford a free and uninterrupted passage for the water.

The foundations must be cut out as nearly the size of the culvert as possible, and the vacant space must be punned up.

All the several culverts to be well punned over with clay, in uniform layers, before the earth is filled in over same.

In all cases the streams must be properly diverted into the culverts.

They are to be built with a stone that will stand well under water, and to be set in good water-lime mortar.

The canal, its banks, and puddles, will continue over them without any variation or difference being made.

The precise spot or scite of the culverts may be varied according to circumstances, by the resident engineer.

There will be a culvert, 3 feet wide and 4 feet high, between lock, No. 1, and lock, No. 2, at the situation shown on the drawing. The extrados of the arch is to be at least 3 feet below the bottom of the canal, it will be turned in arch stones, 15 inches thick, the sides will be 1 foot 6 inches thick, and the invert 9 inches, the whole well backed and fair dressed.

Erect a proper apron and wing walls at the entrances, as will be directed.

There will be another culvert, 3 feet wide and 4 feet high, between lock, No. 2, and lock, No. 3, similar in construction to the last.

There will also be another culvert, 4 feet wide and 4 feet 6 inches high, near the canal, at the spot marked on section; the crown to be 1 foot 8 inches thick, and the sides 2 feet thick, the invert being 12 inches thick, of the general description as before described, with apron and wing walls.

If, upon opening the ground, more or less depth is found advisable for the several works, additions or deductions are to take place, according to the schedule of prices which shall be delivered in.

LIST OF THE DRAWINGS.

EMBANKMENT WALL OF THE

NEW HOUSES OF PARLIAMENT, LONDON.

JAMES WALKER AND ALFRED BURGESS, Esqrs., Engineers.

Plate 36.—Plan, Elevations and Details of the Pile-driving Machines employed in forming the Coffer-dam.

The machine is composed of strong framework: two pieces of wood, from about 30 to 35 feet long, are placed in an upright position, and rested upon sill pieces at the bottom, the space between them constituting the slide or gauge for the iron ram to be drawn up and run down, and the slide is edged with iron, as shown on the plate; a shoring piece is placed on each side, a ladder is also connected with them in the opposite direction, with horizontal ties at different heights, and the whole is further secured by stays and chains at different parts. There are two cross pieces laid athwart the sills, upon which the crab is placed, by which the ram is drawn up; and an apparatus is situated immediately above the latter, usually called a monkey, for disengaging and again securing the ram after each fall, a chain being attached to it, which is carried over a pulley fixed at the top of the framing, and passed down again on the other side to the crab; and the length of the fall is regulated at pleasure by means of a rope fastened to the monkey, which allows of its moving upwards to a certain extent, when its disengagement from the monkey is effected.

DETAILS OF THE

SWING-BRIDGE, SAINT KATHERINE'S DOCKS

THOMAS TELFORD, Esq., Engineer.

Plate 37.—General Plan and Section of bridge, and Details of construction.

Plate 38.—Ditto, Longitudinal Elevation and Section of bridge, to an enlarged scale.

Plate 39.—Ditto, ditto, Plan showing ribs and framing.

Plate 40.—Ditto, ditto, Transverse Sections.

Plate 41.—Ditto, ditto, Details of iron-work.

The section at A—.—.—B, shows the connection with the circular part of the abutment plates; and the Section C—.—.—D shows the connection of the ribs with the straight part of the abutment plates.

Plate 42.—Ditto, ditto, Details of iron-work.

Explanation of Letters of Reference marked on the Plates.

a, Cast-iron plates situated in the carriage way, and secured to the stone-work, at the tail of the bridge, by bolts and nuts keyed into the stone.

b, Cast-iron guide plates attached to the stone-work at each end of bridge.

c, c, c, c, Flanches cast on to the ribs, with cast-iron plates laid across, to support the ballasting. The planks are bolted to these flanches with ½ inch bolts and nuts, and 4½ inches apart in the clear.

The tail plate is cast in three pieces, with joints at the third ribs, d, d.

e, e, Flanches to attach arms of wheels.

f. f. In the plan of abutment plates are flanches for ribs to be bolted to.

Plate 43.—Ditto, Details of working gear to bridge.

Explanation of Letters of Reference marked on this Plate.

a, The cap of the post which lifts off.

b, The cross to carry the upper end of the shaft.

c, The bolts which secure the post to stone-work, of which there are six.

MANCHESTER AND LEEDS RAILWAY.

THOMAS L. GOOCH, Esq., Engineer.

Plate 44.—Plans of construction and Elevation of bridge over the Rochdale Canal at Scowcroft.

Plate 45.—Ditto, Plans showing foundations and Sections through wing walls and arches.

Plate 46.—Ditto, ditto, details of iron girders and framing.

Weight of the Cast Iron-work used in the construction of the Bridge.

	Tons.	cwt.	qrs.	lbs.
4 Main ribs	68	18	0	0
26 Bracing frames	9	9	0	0
4 End, ditto	1	17	0	0
17 Roadway girders	50	8	0	19
Cornice to main ribs	11	0	0	0
Brackets for carrying tension bolts	0	10	0	0
Spandrels	13	0	0	0
	155	2	0	19

Wrought Iron-work.

	Cwt.	qrs.	lbs.
26 Suspension bolts	26	2	0
Gibs and cottrels for ditto	4	0	14
8 Tension rods	191	2	0
16 Coupling boxes for ditto	33	1	15
Gibs and cottrels for ditto	10	1	3
	265	3	4
Total weight of screw bolts	17	1	19

LONDON AND SOUTHAMPTON RAILWAY.

Details of the Locomotive Engines employed on the Line, and constructed by,

GEORGE AND JOHN RENNIE, Esqrs., Engineers.

Plate 47.—Side Elevation of engine.

Plate 48.—Longitudinal Section of ditto.

Plate 49.—End Elevation of ditto.

Diameter of cylinder	13 inches.
Length of stroke	18 ,,
Area of each of the cylinders	132.73 ,,
Steam required in each cylinder, per stroke	1.4 cubic feet
Area of fire-grate for the admission of air	588 square inches.
Total area of fire-grate	1344 or 9.3 square feet
Fuel contained in fire-box	14 cubic feet
Number of brass tubes	118 ,, ,,
Heating surface of ditto	492.78 square feet.
Water evaporated in one hour, with steam equal to 50 lb. pressure on the safety-valve	63.466 cubic feet
Water contained below average water line	36.4 ,,
Steam room	32.5 ,,
Water supplied by each pump, per stroke	56.5 cubic inches.
Number of wheels	6
Diameter of driving wheels	5ft. 6in.
Ditto of small wheels	3ft. 6in.
Cubic content of water in tender tank	118.8 cubic feet.
Weight of ditto when full	3.3 tons.
Time which the water in tender will supply engine	1.87 hours.
Coke fuel necessary to evaporate all the water in the tank	9½ cwt.

Number of revolutions of driving-wheel per minute, at 30 miles per hour	152.76	
Velocity of each piston in feet, per minute, at the average speed of 3 miles per hour	458.28	
Area of steam pipe	9.62	square inches.
Ditto of steam ports	9.56	,,
Ditto of eduction ports	14.87	,,
Ditto of blast-pipe mouth	7.06	,,
Ditto of chimney	159	,,
Ditto of radiating surface	6696	,,
Ditto of communicative surface	70960	,,
Ditto of total heating surface	77650	,,
Total resistance to the motion of the pistons, per square inch of its surface	38.4 lb.	
Volume which the whole steam produced per hour will occupy at the reduced pressure of the preceding resistance	46695	cubic feet.
Ratio of the preceding volume to that expended in effecting a single stroke of one piston	32427	num. of strokes per hr.
Corresponding number of revolutions of driving-wheel, per hour	8106.75	,,
Distance travelled, per hour	26½	miles.
Weight of the engine without water	11½	tons.
Ditto of tender	5½	,,

The safety valve is constructed so as to liberate the steam more freely than by the old mode, the principle being to diminish the resistance in proportion to the opening of the valve, whereas by all previous methods, whether by springs or levers, the resistance is increased 3 feet, and the improved valve is capable of being regulated to any intensity of resistance.

The velocity of the engines have frequently exceeded 41 miles per hour, with light trains.*

* Similar engines were also constructed by Messrs. Rennie for the London and Croydon Railway.

GRANGEMOUTH HARBOUR.

JOHN MACNEILL, Esq., Engineer.

Plate 50.—Transverse Section of Quay wall and coffer-dam, *(see Specification of same.)*

Plate 51.—Ditto Plans of superstructure and foundations.

Plate 52.—Elevation and Sections of timber Pier, *(see Specification of same.)*

Plate 53.—Ditto, Plans of superstructure and Sections of details.

Specification of sundry artificer's work required to be done in erecting and building complete a Quay wall, 100 feet long, including the coffer-dam, steam-engine, and works attendant thereon, upon the banks of the Frith of Forth, situate at Grangemouth Harbour.

GENERAL CONDITIONS.

The following conditions and observations are to be strictly attended to by the different parties tendering for the execution of the proposed work:—

The whole of the materials provided are to be the best in quality of their respective kinds, sound, and well seasoned, and to be applied in the most substantial manner, under the direction and to the entire satisfaction of John Macneill, C.E., and the resident engineer appointed to superintend the works.

The drawings are to be equally binding with the specification; and should anything appear to have been omitted in either or both, which is usually considered necessary for the completing of the several works, the contractor is to execute the same as if it had been particularly described, and is not to obtain any advantage whatever from such omission, but shall apply what may be wanting

to complete the whole, and the works are to be left in a complete state, according to the true intent and meaning of the drawings and specification; and the directions for their correct performance, as given from time to time by the resident engineer, are in all cases to be strictly attended to.

The whole of the stone, timber, iron, and other materials, are to be delivered on the premises, and to be examined by the resident engineer previous to their being worked or used.

It shall be in the power of the resident engineer to reject any part of the materials which he may consider unfit for the work, and cause any part of the work to be altered which, in his opinion, is unsound or unworkmanlike, and not according to the contract, upon three days' notice having been given in writing for that purpose by the resident engineer; and in case the contractor shall refuse, or delay to rectify, or comply with the orders that may be given to him in writing, and shall perform all or any part of the work in an improper manner, or in case the works do not proceed with proper dispatch, the resident engineer shall have power and be at full liberty to suspend the further execution of the works by the said contractor, to take it out of his hands and employ or engage any other person or persons to perform or execute, and to find proper materials for the same, in which case all the costs and charges thereof shall be paid or allowed for by the contractor or his sureties, or allowed or deducted out of the moneys which may be then or become due to the said contractor, the amount of which shall be valued and decided by the engineer, whose award in this and all other cases respecting the works shall be final and binding.

It is also to be in the power of the engineer to direct such alterations to be made in the work during its progress as may be found expedient, which alterations shall not vacate or make void the contract, but shall be performed by the contractor according to the directions he may receive; and the value of the same, whether an addition or a deduction, shall be ascertained by the engineer, and be added to or deducted from the amount of such contract, according to the rate at which such work was undertaken; the award of the engineer, in such case, to be final and binding.

No allowance will be made to the contractor for extra or additional work, unless the same shall be ordered, in writing, by the engineer, and unless a correct account or voucher of the said work is delivered to the engineer within three days of its performance.

The contractor to provide himself with all manner of labour, tools, moulds, implements, scaffolding, centreing-planks, ropes, ladders, hoisting tackle, and materials of every description; carriage, freightage, and every requisite for the completion of the works: he is also to make good any damage done by his work-

men to any part of the works, through carelessness or otherwise; likewise to clear away all rubbish or waste that may arise, when desired to do so by the resident engineer.

To excavate for the foundations of the wall, and all other requisite works as may be found necessary, keeping out the water by placing proper dams, if required, &c.

Should it be deemed necessary at any time to suspend the progress of the works on account of the weather, or any other cause, the engineer shall be at full liberty to do so, and no extra charge shall be made on this account by the contractor.

The resident engineer to be at full liberty to order the discharge of, or dismiss from the works, any man or men for incompetency or misconduct; and the contractor shall not replace them without the written approbation of the resident engineer.

Should any of the materials be lost or stolen from the premises, no allowance can be made for the same.

The works shall be begun as soon as the contracts are signed, and the whole completed within under the penalty of

for the non-fulfilment of same, to be recovered as liquidated damages in any of Her Majesty's courts of law. In case of extra works, additional time will be allowed for same.

To deliver in a paper containing a copy of the estimate, with the quantities and prices upon which such estimate was founded, in order to show that it is a *boná fide* calculation; the same to be left with the engineer, in order that he may be enabled to value any additions or deductions that may arise, according to the prices of such estimate.

The contractor must enter into a bond, with two proper and approved sureties, for the performance of his contract.

The contractor will receive payments, upon producing a certificate from the engineer.

To keep an experienced foreman on the works, who is to be approved of by the resident engineer.

The contractor must include for making good and filling into all irregularities of ground, for the before mentioned length of wall, also for any extra depth of piling at the different parts of the river.

In the event of the ground requiring extra piling under the foundation of wall, for the sleepers to rest upon, it will be allowed for by the engineer, according to the "Schedule of Prices" hereto attached.

COFFER-DAM, &c.

The coffer-dam is to be constructed according to the several drawings and instructions, properly returned at each end, and connected to banks of river by a secure and water tight method.

Dredge a proper trench, of a sufficient depth, to facilitate the drainage of the piles: after the latter are driven, it is to be filled up solid.

SCANTLING OF THE SEVERAL TIMBERS.

	Ins.		Ins.	
Main piles	12	×	12,	or whole timbers.
Waling pieces	12	×	12,	halved ditto.
Outer sheet piling	12	×	12,	ditto, ditto.
Inner sheet piling	12	×	6,	or half timbers.
Filling in planking upon ditto	12	×	6,	ditto.
Furring pieces to ditto	12	×	12,	or whole timbers.
Brace piles	12	×	12,	ditto.
Braces, shoring pieces, ties, &c.	12	×	6,	or half timbers.
Fender piles	12	×	12,	ditto.
Booms	12	×	12,	ditto.

The main or gauge piles are to be driven to the required depths, and at least 2 feet home, into a solid material.

The waling pieces to be in two thicknesses, breaking joint with each other, and bolted to main piles by 2 inch wrought-iron bolts, (these bolts to pass through the sheet piling, out and out) and washers complete.

The ends or extremities of dam are to be splayed off, instead of square, and the waling of same will be in whole timber in one length, strapped upon and secured to side waling, and bolted to the outer gauge-piles, similar to the others, and blocked where required.

The outer sheet piling to be driven to the same depth as the main piles, and exactly square and close to each other; and every pile to be bolted to the waling by an inch wrought-iron bolt.

The inner sheet piling is to be cut off level at the height shown on drawings, and horizontal pieces to be filled in on ditto, and securely bolted by $\frac{3}{4}$ inch screw bolts to furring-pieces, the which are to be strapped to each gauge-pile; the sheet piling will be splayed and fitted together at the angles at each end of the dam.

The brace piles are to be of the same length, and driven with an inclination, as shown on drawings; having a waling piece of whole timber, bolted with a $\frac{3}{4}$ inch wrought-iron bolt, at a level with the bottom of the river, for the diagonal and raking braces to rest upon.

The upright shoring pieces to be two in number to each brace pile, and 2 diagonal shores or braces to each brace pile, secured by 1 inch wrought-iron bolts, and washers at each end.

There will be two 3 inch planks upon both sides of brace piles, bolted to same and shores, secured by 3 inch stirrups, and $\frac{3}{4}$ inch wrought-iron bolts, and 1 raking plank on each, fastened as the others.

Provide all necessary cleats and wedges, to be properly spiked against piles.

The braces at the angles of returns to be in whole timber, and each return will have an additional brace pile and brace, and whatever extra piling and struting may be deemed expedient.

The fender piles to be driven similar to other piles, and to be 6 in number at each end of dam; having booms to same, properly chained, to allow of their free rising or sinking according to the tides.

The greatest care must be taken in the pile driving, to ensure its true direction; all that are improperly driven must be taken up and redrove, and if split or injured they must not be used a second time: wrought-iron hooping to be fitted on the head of every pile.

All the whole piles are to be shod with a wrought-iron shoe, not less than 25 ℔. in weight, and the half timber piles with a similar shoe, 20 ℔. in weight.

Upon the whole of the piles and sheet piling being driven, and the timbering properly secured and braced, the soil enclosed between the sheet piling is to be thoroughly removed, and the space is then to be filled in with good stiff clay, having a portion of gravel mixed with it, or good puddle; the whole worked together, and puddled-in and rendered impervious or water-tight, and as the substance consolidates and sinks, fresh stuff must be filled in and rammed down, always keeping it above the top of the sheet piling.

The base of the dam, both inside and outside, is to have a mass of proper materials constantly piled up against it, with dwarf piling to support same, if required.

PIPES.

Provide and fix two trunks or shoots, consisting of 5 feet of cast-iron pipe, fitted in with proper water-tight valves, and fixed with water-tight joints; the situation and level of same to be pointed out by the resident engineer.

PUMPING.

The contractor to provide and fix complete by the time the dam is constructed, and keep constantly at work, a good low-pressure engine of sufficient power (the power to be of at least 8 horses), to which pumps of sufficient size are to be attached; also pumping apparatus, and all other necessary machinery, to be approved of by the resident engineer.

The engine will be erected in the centre of scite, or where directed, upon a proper foundation and staging; the whole having a temporary engine-house and shed over, and the same over the mill-stones, which will be required for grinding the lime.

QUAY WALL.

Excavate to the depths required for the foundation of proposed wall, as shown upon drawings, the bottom of same being perfectly flat to receive the sleepers, &c.; and working room is to be allowed on both sides; if the soil should be bad and will not stand, sheet piling or planking must be driven to support same.

All the soil and material arising from the excavations or works, that cannot be used for same, are to be removed or carted away.

FOUNDATION.

The foundation of proposed wall to be laid upon 6″ planking, supported by sleepers 12″×8″; the sheet piling will be of red pine timber 8″ thick, having an 18 lb. shoe to each, and it must be driven in the most careful manner, with waling pieces 15″ × 8″, bolted to them by 1 inch wrought-iron bolts.

CONCRETE.

The concrete used in the founding of the walls, &c., to be mixed in the proportion of 7 measures of gravel to 1 of ground stone lime, of approved quality, the stone lime to be ground to powder by mill-stones attached by a gear to the steam-engine; the materials above stated are to be well mixed without any water, but by mere manual labour, when this is done a sufficiency of water is to

P 2

be added, and the whole well mixed together, it is then to be wheeled away in barrows, and pitched from a height of at least 10 feet in all its stages and layers; where it cannot be pitched, it is to be well puddled and trodden down by men, and well cemented together, and brought to a solid bearing to receive the sleepers, planking, &c.

The filling in concrete to be of similar materials, mixed in a like manner, in the proportions of 1 of lime to 10 of gravel, pitched and laid in layers of 9 or 10 inches in thickness.

The concrete is to be kept perfectly clear of the water.

STONE WORK.

The wall and counterforts to be carried up of the several dimensions shown and figured on the drawings.

The footings of proposed wall to be in large sizes, the stones not less than from 4 to 5 feet by 2 to 3 feet, and 12 inches thick, of good tough quality, from the   quarry, squared and fair worked and laid in mortar; the courses properly breaking joint with each other, and according to the drawings.

The wall to be carried up in courses varying from 12 to 15 inches in thickness, and the sizes to be about 3 feet 2 inches by 2 foot for headers, and 3 feet by 1 foot 6 inches for stretchers, and to be laid 2 stretchers to 1 header, and properly bonded together.

If the engineer should think fit to have the stone from some other quarry, instead of from the   quarry, and the distance should be greater, it will be allowed for extra.

The whole of the outside stone to be carefully selected as to colour and quality, and to be laid in its natural or quarry bed, the upper and lower bed of every stone to carry its full thickness from front to back, so that the bearing both above and below may be perfectly square and level throughout: no pinning in levelling will be allowed; each stone is to be brought firmly to its bed by a wooden mallet.

The top course of stone to wall forming the curb to be good whinstone, and to be 12 inches thick, in large sizes, and rounded on the edge, and to be placed round the whole width of wall, and well joggled together; the pitching or paving is likewise to be of whinstone.

All the masonry to be worked with chisel drafts round their faces, beds, joints, and backs, and to be picked between the drafts, so that upon applying a ruler

upon the face no part shall be above them, and no more space than $\frac{1}{8}$th of an inch below them; the outside faces being worked with exact regularity and neatness.

The whole of the stones are to be worked on the ground, and to be set with lewises and proper tackle.

The whole of the stone-work is to be laid throughout on a thick bed of mortar, of the following description—one measure of good stone lime, one measure of puzzolana, and two measures of sharp clear sand, free from rubbish, dirt, and other impurities.

The lime is to be slacked and mixed with puzzolana and sand, they are then to be passed together in a dry state through screens, and the water added.

The mortar is to be well tempered and worked to a tough and proper consistency, and ground by edge stones, worked by a gear from the steam-engine.

No more mortar is to be made at a time than can be consumed in the day's work.

The lime to be brought in small quantities, and to be kept under an enclosed shed, so as not to be injured by exposure to the weather.

The wall to be properly returned for a space of 30 feet from the face in similar masonry, and to be carried as deep as the nature of the ground may require; the space enclosed by the walls to be properly pitched or paved with whinstone, 12 inches in thickness, as before described.

Lay in wall 3 tier of oak plates, $12'' \times 9''$, to secure fenders to; the top plate is to have a return piece, dovetailed and spiked to same at every 10 feet.

The fenders are to be of oak 9 inches wide, and projecting 7 inches from face of wall, and to be bolted on with inch screw bolts, having oak cleats, &c., morticed and tenoned on each side, and spiked to plates; and fix iron rings to same in a secure manner.

Specification of the timber Pier, to be erected on the Frith of Forth, at Grangemouth Harbour.

GENERAL CONDITIONS.

The following conditions and observations are to be strictly attended to by the different parties tendering for the execution of the proposed work:—

The whole of the materials provided are to be the best in quality of their respective kinds, sound, and well seasoned, and to be applied in the most substantial manner, under the direction and to the entire satisfaction of John Macneill, C.E., and the resident engineer appointed to superintend the works.

The drawings are to be equally binding with the specification; and should anything appear to have been omitted in either or both, which is usually considered necessary for the completing of the several works, the contractor is to execute the same as if it had been particularly described, and is not to obtain any advantage whatever from such omission, but shall apply what may be wanting to complete the whole, and the works are to be left in a complete state, according to the true intent and meaning of the drawings and specification; and the directions for their correct performance, as given from time to time by the resident engineer, are in all cases to be strictly attended to.

The whole of the stone, timber, iron, and other materials, are to be delivered on the premises, and to be examined by the resident engineer previous to their being worked or used.

It shall be in the power of the resident engineer to reject any part of the materials which he may consider unfit for the work, and cause any part of the work to be altered which, in his opinion, is unsound or unworkmanlike, and not according to the contract, upon three days' notice having been given in writing for that purpose by the resident engineer; and in case the contractor shall refuse, or delay to rectify, or comply with the orders that may be given to him in writing, and shall perform all or any part of the work in an improper manner, or in case the works do not proceed with proper dispatch, the resident engineer shall have power and be at full liberty to suspend the further execution of the works by the said contractor, to take it out of his hands and employ or engage any other person or persons to perform or execute, and to find proper materials for the same, in which case all the costs and charges thereof shall be paid or

allowed for by the contractor or his sureties, or allowed or deducted out of the moneys which may be then or become due to the said contractor, the amount of which shall be valued and decided by the engineer, whose award in this and all other cases respecting the works shall be final and binding.

It is also to be in the power of the engineer to direct such alterations to be made in the work during its progress as may be found expedient, which alterations shall not vacate or make void the contract, but shall be performed by the contractor according to the directions he may receive; and the value of the same, whether an addition or a deduction, shall be ascertained by the engineer, and be added to or deducted from the amount of such contract, according to the rate at which such work was undertaken; the award of the engineer, in such case, to be final and binding.

No allowance will be made to the contractor for extra or additional work, unless the same shall be ordered, in writing, by the engineer, and unless a correct account or voucher of the said work is delivered to the engineer within three days of its performance.

The contractor to provide himself with all manner of labour, tools, moulds, implements, scaffolding, centreing, planks, ropes, ladders, hoisting tackle, and materials of every description; carriage, freightage, and every requisite for the completion of the works: he is also to make good any damage done by his workmen to any part of the works, through carelessness or otherwise; likewise to clear away all rubbish or waste that may arise, when desired to do so by the resident engineer.

To excavate for the foundations of the wall, and all other requisite works as may be found necessary, keeping out the water by placing proper dams, if required, &c.

To excavate for the foundations of all works that may be required, placing dams, &c., if found necessary.

Should it be deemed necessary at any time to suspend the progress of the works on account of the weather, or any other cause, the engineer shall be at full liberty to do so, and no extra charge shall be made on this account by the contractor.

The resident engineer to be at full liberty to order the discharge of, or dismiss from the works, any man or men for incompetency or misconduct; and the contractor shall not replace them without the written approbation of the resident engineer.

Should any of the materials be lost or stolen from the premises, no allowance can be made for the same.

The works shall be begun as soon as the contracts are signed, and the whole completed within under the penalty of
for the non-fulfilment of same, to be recovered as liquidated damages in any of Her Majesty's courts of law. In case of extra works, additional time will be allowed for same.

To deliver in a paper containing a copy of the estimate, with the quantities and prices upon which such estimate was founded, in order to show that it is a *bonâ fide* calculation; the same to be left with the engineer, in order that he may be enabled to value any additions or deductions that may arise, according to the prices of such estimate.

The contractor must enter into a bond, with two proper and approved sureties, for the performance of his contract.

The contractor will receive payments, upon producing a certificate from the engineer.

To keep an experienced foreman on the works, who is to be approved of by the resident engineer.

The timber, unless otherwise described, is to be of the best Memel, Riga, or Dantzic, free from sap, shakes, and defects, also large, loose, or dead knots.

All the iron to be wrought, and of the best merchant's iron, which is to be properly tested, as the resident engineer may direct.

The work will consist of 5 bays, of 19 feet 5 inches each, leaving 1 foot 6 inches on the outside at each end, making in all about 100 feet.

The contractor to prepare for the driving of the piling, as may be found necessary.

SCANTLINGS OF THE TIMBERS.

	Ins.		Ins.
Front and side piles	12	×	12
Ditto, ditto, walls	12	×	6
Cross beams	12	×	12
Top beams	12	×	9
3 pair of front braces	9	×	9
Side braces	12	×	6

Straining pieces	9 × 9
Struts to same	9 × 9
Diagonal struts to same	6 × 6
Cross sleepers or sills situated on the banks	12 × 3
Longitudinal sleepers at top of bank .	12 × 6
Fenders	12 × 6

The whole of the piles to be driven, until a good solid and sufficient foundation is found.

The front piles to be two in number to each pier, being properly connected to side wales by wrought-iron straps, 4″ × 1″ round both piles and bolts; these straps will also have a hole wrought in same with a proper shoulder to receive the bolt, which secures front wale; the heads of the piles are to be properly morticed 6 inches into cross beams.

The side piles to be in a single row, and in a line with the centre of front piles, and they will be morticed 3 inches into bolsters upon top of same, 12″ × 6″, upon which the cross beams are laid; all the piles are to be shod with a proper wrought-iron shoe, not less than 25 ℔. in weight.

The front wales are to be secured to the straps round front piles, by an inch wrought-iron bolt; the strap being properly prepared to receive same, as before described. The side wales to be notched on and secured to front main piles by straps and bolts, as before described, and to braces and side piles by inch wrought-iron bolts, nuts and washers, the ends of same resting upon sills; to have cleats drove tight upon them, running from one sill to the other, and screwed to same with $\frac{3}{4}$ inch bolts and nuts, as shown on drawing; these cleats likewise support the ends of the braces.

The cross beams to be secured to front piles and bolsters by mortices and tenons, as before described.

The top beams to be secured to bolsters and cross beams by inch wrought bolts and nuts, running right through each of them, and to straining pieces by two 1 inch wrought screw bolts.

The three front top beams to be bolted together by $1\frac{1}{4}$ inch wrought bolts and nuts, having a loose ring attached on the outside face of beam, as shown on drawings. And 3 inch planking will be laid upon top beams, properly fastened with jagged spikes.

The front, or face braces, to be as shown on drawings, having 3 inches notched out of each at the crossing, where they are to be halved and fastened with an inch bolt and nut; the bolts to the first pair passing through the front waling, the lower end to be let into the pile and secured by 2 inch straps and

bolts, the upper ends also to be morticed and tenoned into piles, and spiked, and to have a cleat bolted on to top of same, which likewise supports the struts to straining pieces: the second pair from the front to be bolted together at their intersection, and secured to side piles by mortices and tenons, and connecting irons and bolts at the lower end, and having cleats bolted on the upper end: the third pair of braces from the front to be morticed and tenoned into piles, and secured to side piles by 1 inch wrought screw bolts, they will rest upon, and be morticed and screwed into a sleeper, 6 inches thick, laid on bank to receive same.

The side, or framed braces, to be secured to side piles by bolts, as before described; the upper end being fastened to the cross beams by 2 inch stirrup irons, properly wedged and spiked, to obviate any deficiencies in the different thicknesses of the timbers; the end resting on the sleepers or sills to be spiked to same: they will likewise be supported by cleats, as before mentioned.

The straining pieces to top beams to be bolted to same, as before described; the struts to same to be tapered off or reduced at the end, to allow the diagonal struts to fit close to them, and they will each be morticed, tenoned, and spiked into piles; cleats will be bolted on immediately under and fitting to them, the bolts passing from wale to wale.

The diagonal pieces will likewise be bolted together at their heads by $\frac{3}{4}$ inch bolts.

The scarfings to the several timbers to be at least 2 feet long, and thoroughly strong, and secured together by bolts and irons properly wedged.

The paving of the surface of the platform to be laid with pitching stones, 12 inches in thickness, upon planking to receive same, having a wrought curb, as shown on drawing; the whole to be of tough whinstone, set with mortar, composed of good stone lime, gravel, and puzzolana; the curb will have irons, 3 inches by 1 inch, let into the joints, and well run with lead, and screwed on to planking to prevent their being shaken.

The banks to be properly consolidated and rammed with hard rubbish, to receive pitching stones, 12 inches in thickness; the said pitching to be properly laid, and the bottom course to be well secured and cramped together.

LAND-TIES.

Drive a pile 25 feet deep of whole timber opposite each pier, shod similar to the other piles, and 60 feet from face of front piles, secure to same a $1\frac{1}{2}$ inch tie bolt, with nuts and washers, the other end will be fastened to an iron strap, which is fastened to cross beam.

The strap to be $1\frac{1}{2}$ inches thick at the sides, and 2 inches in front, and 4 inches wide, it will be 5 inches in centre of front, properly shouldered with inch bolt to same ; the tie-bolt will be coupled at every 10 feet, having a mooring-ring fastened to the outer extremity : should the tie-bolt swag, so as to require any supports in its length, stirrup-irons must be provided in order to keep it in its place. The whole of the iron to be wrought.

The fenders to be as shown on drawings, having their several heads properly tenoned into the beams, and fastened to walls and piles by 1 inch bolts and nuts.

The cross sleepers will be properly secured to timbers at each end, as may be found necessary, also properly spiked to longitudinal sleeper at top of bank. The ground is to be well rammed and secured for same, and all the sleepers must lay upon proper stone landings in large sizes, 12 inches in thickness.

The longitudinal sleeper to be properly supported, and well secured to the framing; fillets, 18 inches apart, will be nailed to same, for the planking to be secured to; the latter being made 3 inches thick, and spiked as may be found necessary.

The whole of the framing effecting, and immediately connected with the surface or platform, must be framed so as to give an inclination or fall towards the river.

The greatest care must be taken in the pile-driving to ensure their true direction, as all piles improperly driven must be taken up and redrove, and all that are split or injured will not be allowed to remain ; iron hooping must be fitted to the head of each pile in the driving, and generally frame and fasten the timbering properly together finding all bolts, mortices, and tenons, where required.*

* It is proper to mention, that the Quay wall was not erected precisely according to either of these plans.—Editor.

MIDLAND COUNTIES RAILWAY.

CHARLES VIGNOLES, Esq., Engineer.

Plate 54.—Plans and Elevation of the bridge over the River Soad, at Stamford.*

Plate 55.—Ditto, Details of the iron piles, girders, &c.

This bridge is constructed principally of cast-iron, and forms a very interesting subject, being almost an imitation of the timber pile bridges in common use for crossing rivers; and we believe it is the first instance of the application of iron piles for such a purpose.

* This bridge was designed by T. J. Woodhouse, Esq., the Resident Engineer.

LONDON AND BIRMINGHAM RAILWAY.

ROBERT STEPHENSON, Esq., Engineer.

Plate 56.—Plans and Elevation of bridge for road from Banbury to Luterworth. *(See Specification of same.)*
Plate 57.—Ditto, Details of Iron-work.
Plate 58.—Ditto, ditto.

Specification of bridge for road from Banbury to Luterworth.

This road passes over the railway at an angle of 28°, at a point where the depth of cutting is 26 feet 6 inches.

The bridge consists of a central opening, with three small archways on each side; the slopes ending in wing-walls, which extend to the edge of the cutting.

The central opening is 30 feet wide on the square, and is spanned by six trussed frames or ribs of iron, resting on piers at each side.

Each frame consists of 2 cast-iron main ribs, abutting at the crown and having three ends attached to 2 wrought-iron ties, which are stretched beneath them, and united in the middle.

The ribs and ties are kept at the proper distance from each other by cast-iron open work placed between them, and acting the part of struts.

The main ribs of the upper sides are horizontal, and have flanges projecting on each side, to admit of the roadway plates (hereinafter described) being bolted to them: the under sides are curved with a flat circular curvature, and have tables projecting on each side in the form of rounded mouldings, their breadth being greatest in the middle of the rib, and gradually decreasing to nothing at each end.

Similar mouldings run along the ribs at the distance of 2 feet from the bottom, and the thickness of metal between them is 1 inch.

At the meeting at the crown the ribs present a section of 2 feet in depth, with a uniform thickness of 4 inches; their ends are rounded into circular arcs, which fit into corresponding sockets in the sides of the cast-iron key, hereinafter described.

The ends of the ribs resting on the bearing piers are cast with circular holes, to admit the bolts which attach the wrought-iron ties; round these holes the metal is swelled into bosses, 4 inches thick, and the same thickness is continued to the bottom of the ribs, which is slightly rounded.

The ends of the ribs just described rest in chairs, forming part of a cast-iron plate, which extends along the whole length of the piers, which is run with Roman cement, and firmly bolted to a course of stone, hereinafter described.

The wrought-iron ties are attached to the ribs by bolts passing through the holes above-mentioned, and are united in the middle by a connecting link and bolts. On this joint, which it encloses in a kind of box, rests the main strut.

It consists of a cast-iron pillar, with fins projecting from the sides; the upper part is cast hollow, in the form of a rectangular pipe, to admit of a strong bar of wrought-iron being inserted, and firmly riveted in its place.

This bar extends through a hole in the key, and by means of a strong thread screw and nut working against the underside of the key admits of an adjustment of the length of the strut.

The cast-iron open work, between main ribs and the ties, are shown on the drawings. The top rests firmly against the bottom of the ribs, and is attached to them by means of feet projecting at intervals and fastened by wrought-iron wedges into corresponding sockets cast on the side of the ribs.

The bottom is cast in the shape of a three-sided box, the top resting on the ties, the sides enclosing them; and the box is completed by pieces of boiler-plate being screwed on beneath, neatly fitted to the edges of the box and cut to the exact width.

The ties are kept at the proper distance from each other by pieces cast at intervals on the top of the above-mentioned box, and fitting accurately between them.

The meeting-plate consists of a cast-iron plate, extending the whole width of the bridge, with the keys of the different ribs cast on it at the proper intervals.

The parts between the keys are strengthened by fins projecting from each side.

The keys themselves, against which the ribs abut, are cast with sockets on each edge, for the reception of the rounded ends of the main ribs, and with holes through the centre, to admit the wrought-iron bar of the main strut, before described.

The outside key has its face cast with a sunk panel, the edges of which are neatly rounded; it has also a plate falling beneath the general level of the bottom, in order to hide from view the top part of main street.

A long strip of boiler-plate, $1\frac{1}{2}$ inches thick, and 1 foot wide, is to extend the whole width of the bridge, at the point where the main ties unite, and it must be firmly secured to the under edges of the main struts.

The roadway-plates are of two sizes, the one to extend over four ribs, the other over two; and they must be so arranged that the smaller plates may break joint alternately with the larger.

At the points where they rest upon the main ribs they are to have projecting cleats, fitting exactly to the sides of the upper tables of the ribs, to which they must be bolted down by wrought-iron bolts alternately on each side.

They are also to have diagonal flanges cast on their under sides between each of the ribs, and projecting to the extent shown on the drawings.

The whole of the joints of the roadway plates are to be accurately fitted and caulked with oakum, so as to be perfectly water-tight; and a layer of concrete, 6 inches thick, is to be laid over the whole surface.

A string course of cast-iron, in the form of a torus moulding and plinth, is to be bolted to the top of the exterior ribs, and to the road-plates by lugs occuring at intervals of 2 feet.

It is further steadied by wrought-iron stays attached at one end to these tugs, and at the other to the inner sides of the plinth.

Sockets, as shown, are to be cast on the interior at every 2 feet, for the reception of the standard of the cast-iron railing hereinafter described, and the inside plate is to be cast loose, and afterwards screwed on.

The railing is to be of cast-iron, in lengths of 10 feet, as near as may be.

The standards of the railing are to be fastened into the sockets of the string-course, above described, with wrought-iron wedges, and the middle standard of each length is to be steadied by a bracket, or knee, riveted to it and to the top of the torus moulding.

The joints of this railway are to be made with half-laps, and neatly and accurately riveted together.

The form and dimensions of the brickwork and masonry of the bridge are shown on drawing.

The main piers, on which rest the iron frames, are to be of brick faced with stone toothing into the brickwork, alternately to the depth of 2 feet and 2 feet 6 inches.

The faces of these piers are broken by stone pilasters, standing forward 9 inches from the general face; the whole is carried to a height of 4 feet 6 inches above the surface of the roadway, and is crowned by a large stone cap, which must be formed of a single stone.

A course of Bramley Fall stone, 2 feet deep, and bedded in the brickwork 3 feet 6 inches, runs along the whole length of the pier at the part where the iron frames rest.

None of the stone forming this course are to be less than 3 feet long; and they are to be firmly dowelled together and cramped on the top with 2 wrought-iron cramps to each joint, 1 square inch in section, 14 inches long, and leaded into the stones to the depth of 3 inches.

A brick wall, 3 feet thick, is to be built between the ribs up to the level of their tops.

The arches on the slopes are of brick, 8 feet span on the square, and 1 foot 6 inches thick, with stone quoins or voussoirs on the face, toothing into the brickwork alternately to the depth of 2 feet and 2 feet 6 inches.

The whole of the arches must be laid with spiral courses at right angles to the face.

A solid backing of brickwork must be carried up to the height shown by the dotted lines.

The arches rest on brick piers, faced with stone to the depth alternately of 2 feet and 1 foot 6 inches; they are to have stone imposts, as shown, from which the arches spring.

The wing-walls begin to batter at the rate of 1 inch per foot at the set off, shown on drawings; they are stepped up the slopes in the manner shown by the dotted lines, and are carried out to the edge of the cutting, where they end in pilasters of ½ brick projection, and are crowned with caps of stone 9 inches deep in the middle.

A torus moulding of stone, and a brick plinth of the exact form and dimensions of that specified over the iron ribs, runs along the whole extent of this bridge.

The torus must return round the pilasters, and the corners must in every case be formed of whole stones cut to the proper form.

All the castings of this bridge must be of No. 1 iron, and the malleable iron must be of the best scrap iron.

Great care must be exercised in making all the joints and fittings of the iron-work perfectly true and accurate, and every part must be brought to an equal and uniform bearing before the centreing or supports are removed, so that there shall be no risk of any part being subjected to unequal or cross strains.

The whole of the iron must be submitted to such trials of its strength as the engineer may consider necessary, and the contractor must be at the expense of all the means or apparatus required ; and should any part of the iron-work fail, or be damaged, he must replace them by others fully capable of undergoing the trial.

The whole of the iron-work must be painted with 2 coats of paint, after it is erected.

For other particulars of materials and workmanship see "General Stipulations."

SECHILL RAILWAY.

ROBERT NICHOLSON, Esq., Engineer.

Plate 59.—Plan and Elevation of bridge over the Cramlington Railway.
Plate 60.—Ditto, Details of timber arch and iron-work.

This bridge is of similar description to a bridge on the North Shields Railway, by the same engineer, and represented in another part of the work; but the span in this case is much greater, and it has been found to answer every purpose.

DETAILS OF

LOCK ON THE RIVER CAM.

Plate 61.—Plans, Elevations, Sections, and Details of the lock.

GLASGOW, GREENOCK, AND PAISLEY RAILWAY.

JOSEPH LOCKE, Esq., Engineer.

Plate 62.—Plans, Elevations, and Sections of the bridge over the Black Cart Water.

Specification of bridge for the purpose of carrying the railway over the Cart Water. It shall be built of the form and dimensions shown on the drawing.

A platform of stone shall be laid under each of the piers, 2 feet thick, and no stone shall contain less than 24 superficial feet; each stone shall be squared and jointed; the joints shall be filled with Roman cement. The platform shall be laid, at the depth shown on the drawing, on a level bed of concrete, 2 feet thick; it shall consist of 5 parts of clean round gravel, and 1 part of water lime.

On each of these platforms shall be laid 6 sleepers in the longitudinal direction of the bridge; they shall be secured by 1½ inch screw bolts, 4 bolts in each, let 9 inches into the stone, and securely Lewis wedged. On these bearers shall be placed the trusses which support the bridge.

The sills of the trusses shall be joggled 3 inches into the bearers, and securely bolted with 1 inch bolts; 2 bolts into each end of every bearer.

The uprights shall be tenoned into the sills and crown trees, and shall be secured by wrought-iron knees ¾ inch in thickness, each end of such knees shall be at least 2 feet 6 inches in length, and 4 inches in breadth, and shall have 6 screw bolts in each knee.

It may be as well to observe here, that whenever screw bolts are named, bolts and nuts are meant, and that in every case the thickness of the nut shall be equal to the thickness of the bolt, and that the bolt shall project half its thickness through the nut.

A row of sheathing piles, not less than 15 feet long, and 6 inches thick, shall be driven quite round the platform in the river, and three sides of each of the others. The walings of all shall be secured to the stone in the same manner as the bearers—viz., by screw bolts let 9 inches into the stone, and securely Lewis wedged. Great care must be taken in driving these sheathing piles, that the whole row on each side is preserved on the same plan, and that the joints are kept as close as possible.

The footings for the stays that support the longitudinal beams shall be securely bolted to the crown trees with 1 inch bolts, and the stays shall be secured at each end by iron knees of the same dimensions as those before described.

The scarfes in the longitudinal beams shall be united by an iron plate, not

less than 6 feet long, fixed on the upper and underside of the beam, with screw bolts through the whole, and no scarfe will be allowed on any pretence whatever, except where shown on the plan.

The trusses which stand upon the footings for the stays shall be fixed at top and bottom in the same manner as those in the truss below, and the beams shall be securely bolted to the crown trees of these trusses with 1 inch bolts.

Transverse stays shall be chase-morticed into the longitudinal beams, over each of the trusses, and also in the intervals between them. There are in all 10 transverse stays, extending from side to side of the bridge. An iron strap shall be fixed on all these, (except such as stand over the trusses,) these straps shall be put on from each side of the bridge, and shall nearly meet in the middle, having keys made so as to draw the beams tight against the transverse stays, which shall be well secured with screw bolts through the whole.

The diagonal stays shall be bolted to the trusses, and to the underside of the longitudinal beams, with $1\frac{1}{4}$ inch screw bolts.

All the masonry shall be built on a level bed of concrete, 2 feet thick.

The piers shall be built of ashlar, tool dressed, laid header and stretcher, 1 foot and 2 feet, alternately.

The abutments shall be built of stone, 4 feet 6 inches thick, in courses of about 8 inches. Rough rustic on the face, with $\frac{1}{2}$ inch chamfor. They shall have ashlar quoins of the same depth as each two courses. Four throughs shall be put into each course, as shown on the drawing. The backing may be of rubble.

The wing walls shall be faced with a similar description of stone-work as the abutments—they shall be backed with rubble.

The string course and pillars shall be tool-dressed.

All the rubble-work in the bridge shall be built in courses, of stones of a size as large as a man can conveniently lift, and each course shall be flushed up with scabblings and well grouted.

The whole of the iron work shall be of the best British scrap. The whole of the timber below the footing of the stays that support the longitudinal beams shall be of larch, and also the sleepers on the embankment ends; and all other timber shall be of the best, straight-grained crown memel, or crown Dantzic.

A wooden railing shall be fixed the whole length of the longitudinal beams on each face. It shall be formed of uprights 4 feet 6 inches high, morticed into the longitudinal beams, and also into a top rail, which shall be half round on the top. Cross braces shall be morticed and tenoned into the uprights, and each other, as shewn in the drawing.

The whole bridge shall be planked across with Dantzic deck deals, close jointed, and well nailed with 7-inch spikes, and covered with a thick coat of boiled pitch, mixed with quick lime, and covered with coarse sand, or rather oxide of iron, if it can be procured.

LEEDS AND SELBY RAILWAY.

JAMES WALKER, Esq., Engineer.

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JOHN PHILLIPS, Esq., Surveyor.

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CAPTAIN W. MOORSOM, Engineer.

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SOUTH EASTERN RAILWAY.

W. CUBITT, Esq., Engineer.

Plate 69.—Details of the Timber Viaduct to the Bricklayers' Arms Station. Details of Chairs and Rails, and Barlow's Patent Metal Keys.

This viaduct consists of pile piers, twenty feet apart longitudinally, each pier being composed of three piles. Two planks were afterwards bolted transversely on each side of the piers, just above the surface of the ground, the bolts passing through the piles. The ends of these planks were supported on short longitudinal bearers, each resting on two short piles. Wooden wedges were interposed above the bearers, in order to accommodate any unequal settlement of the main structure with the shorter pile supports.

LONDON AND BLACKWALL RAILWAY.

Messrs. GEORGE STEPHENSON & BIDDER, Engineers.

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* Plate 15 is stated in the description to be "Details of the *Stockport* Viaduct," whereas it is the "*Congleton*," as corrected in this list.

T. C. Savill, Printer, 4, Chandos-street, Covent-garden.

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BY

S. C. BREES, C.E.

LATE PRINCIPAL ENGINEER AND SURVEYOR TO THE NEW ZEALAND COMPANY,
FROM THE YEAR 1842 TO 1845;
AUTHOR OF "GLOSSARY OF TERMS USED IN CIVIL ENGINEERING," "PRESENT PRACTICE OF SURVEYING AND LEVELLING," ETC.

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"THIRD SERIES OF RAILWAY PRACTICE,"

IS, BY PERMISSION,

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SAMUEL CHARLES BREES.

PREFACE.

THE present volume consists mainly of a translation from the "*Portefeuille de l'Ingenieur des Chemins de Fer, par* M. AUGUSTE PERDONNET, *formerly a pupil of the Polytechnic School, Professor at the Central School of Arts and Manufactures, and Engineer in Chief to several Railways; and* CAMILLE POLONCEAU, *Director of the Alsace Railway, formerly a pupil of the Central School of Arts and Manufactures,*" the value of which is generally admitted both on the Continent and in this country.

The Editor feels some diffidence in laying the volume before the profession, being well aware that the importance of the subject demands an engineer of the highest pretensions and standing. Since, however, it is seldom that one possessing these advantages can afford the requisite time, he trusts that his humble efforts will meet with some countenance and consideration.

To the gentlemen who have so kindly contributed subjects to the present volume, the Author returns his best acknowledgments, and his thanks are due to his young friends, Messrs. RICKMAN, ROBINSON, MORRISON, and others, for the assistance they have rendered him in the reduction of the drawings, measurements, tables, &c., into English.

43, *Lincoln's Inn Fields.*

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INTRODUCTION.

THE distinguished authors of the *Portefeuille de l'Ingenieur des Chemins de Fer** having left nothing to be desired in the several subjects treated upon, the Editor has seldom found occasion to carry their statements or descriptions any further.

The numerous observations on earthworks are particularly valuable, being the result of practice; also the remarks on the most efficient system of rails, and the formation of the line. These comprise nearly everything that can be written concerning the execution of cuttings, their drainage, &c., and the results, in every instance, show the importance of doing everything well *at first.*

Thus we find that side ditches were soon considered indispensable along the tops of cuttings; these were followed by longitudinal ledges or steps, and even by second ditches at a lower level. Improvements continued until deep, vertical, dry drains filled up with loose stones were introduced on each side, in a similar manner to the lining of canals. Surface drains were also formed down the slopes; and, carrying out this principle, it has struck us that extensive cuttings might be still further improved by a closer approximation to nature.

Now, if we take the form of a railway cutting, and compare it with a natural ravine, we shall find that there is but little resemblance between them, and much of the surprise on viewing the effects of moisture on the slide slopes of artificial works ceases, when we consider the really small provision that is usually made for carrying off the water, compared with that supplied in the works of nature. The water from the higher levels of a ravine is carried down by auxiliary valleys on each side, and the entire *lay of the country* between the latter, tends to the accomplishment of this grand system There is a summit level between the side valleys, the ground falling in each direction with a regular

* Paris: Librairie Scientifique-Industrielle, de L. Mathias. 1846.

systematic series of surface drains and feeders in the shape of streamlets and brooks, by which the water is carried away. It is very rare to find a straight face, like a railway slope, extending any distance, as the action of nature necessarily breaks the surface and forms side valleys.

We therefore offer a suggestion, that, independent of the precautions commonly taken to relieve the lower strata from the weight of the upper in the execution of important earthworks, a proper examination of the levels of the country along each side should be made, and lateral drains constructed, of much greater extent than heretofore, at certain intervals, the distances to be regulated by the inclination of the land. The shape of the slopes between these side gulleys might also be made of more suitable form, and the means to be employed in their maintenance and support constitute a part of the original design, rather than be left to chance or futurity, as at present.

The dimensions of the lines of railway have not undergone any alteration since the appearance of the French work.*

The gauge on all the lines in France is 1^{m} 50 from centre to centre, or the 4 feet 11 inch English gauge, and the interspace 1^{m} 80 (5 feet 11 inches.)

A royal commission was appointed by the English government to examine into the question respecting the most advantageous dimensions for the gauge of railways, when the commissioners came to the following conclusions, and made their report, in the beginning of last year, (1846.)

" 1st. That an increase in the gauge of way would not present any advantage, as concerns the safety and comfort of the passengers.

" 2nd. That greater speed may be attained with the wide gauge than with the narrow, but there would be some danger in exceeding the *maximum* velocity at present attained upon railways of the ordinary gauge, according to the present construction.

" 3rd. That the narrow gauge is preferable for the transport of goods, and the most appropriate for the exigencies of trade.

" 4th. That the employment of the wide gauge necessitates greater expenses in the formation, and any reduction which might result in the cost of maintenance, or in locomotive power, does not appear to be of such a nature, as to compensate for the increase in the first outlay.

" 5th. It is very important that the gauge should be uniform throughout

* The remainder of this Introduction is principally taken from the " Portefeuille de l' Ingénieur des Chemins de Fer."

the same country. Great inconvenience has resulted from the break of gauge on the Great Western and Gloucester lines.

"6th. The commission see no reason for changing the narrow gauge, which is 4 feet 8½ inches, corresponding to 1^m 50 (4 feet 11 inches) from the centre of one rail to the centre of the other, in France."

The railways laid down with the narrow gauge in England, at the date of the report, amounted to 1901 miles, while that of lines formed of the broad (7 feet) gauge, amounted to 274 miles only, and 122½ miles of the Irish gauge (5 feet 3 inches.)

Experience in the management of railways has led generally to an increase in the size of the stations, especially of those for goods. The goods department on railways cannot be conducted with sufficient economy to compete successfully with canals, unless the depôts afford extensive accommodation.

Attention has been much directed the last few years to the processes employed in the preservation of timber sleepers, and a description of these experiments will be found among the documents.

The opinion of the profession, which has been so long favourable to the double T rail, has at length changed in France, experience having shown the impossibility of reversing this rail upon one of the mushrooms becoming worn. Many engineers now give a preference to the simple T rail.

M. Prisse, formerly pupil of the Central School of Arts and Manufacture, and Chief Engineer of the West Flanders Railway, has written to us in the following terms:—

"M. Cabry and I have returned from England perfect converts to the value of the description of rails which you have so long adopted.* We have seen rails weighing as much as 82 lbs. per yard, but we did not find that they were the best.

"We have adopted a similar rail to yours for our railway since our return, comprising a supply equal to 6000 tons, which has been finally let."

We understand that the worn-out rails on the Grand Junction Railway have been replaced by others formed of the single T pattern.

A single *champignon* rail has also been adopted on the line from Avignon to Marseilles, and M. Gervoy has shown us the model of a rail of the same kind which he intends for the line from Tours to Nantes.

* See the rail of the Versailles line (left bank,) Plate 4.

The surface on which the wheels run of these new rails is always rounded *more or less.*

Rails of the weight of 37 kilogs. per metre, (74 lbs. per yard,) are generally adopted in laying down new lines where the traffic upon them is expected to be great. They are as much as 5^{m} 50 (18 feet) long, on the railway from Orleans to Vierzon. It is necessary for the rails to possess great resistance, in order to support the heavy engines in present use, but it remains to be seen whether the most massive rails uniformly present the greatest resistance. When the quality of the iron and the form of the rail are the same in two different models, there is no doubt that the largest is the most solid, but the manufacture becomes more difficult as the weight of metal is increased, whereby it suffers in quality.

The rails on the Northern Railway, which equal a weight of 50 kilogs. per metre (61 lbs. per yard,) are at present supported on four sleepers, but an additional one has been proposed.

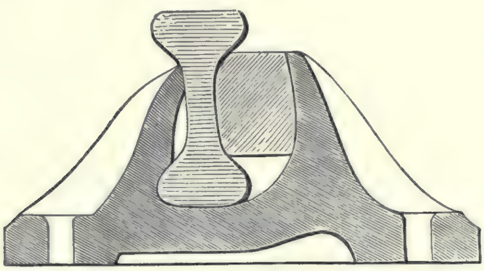
The manufacture of rails is still conducted by the old method at some works, as at that of the Hayange foundry, for instance, or with the upper layer of the bundles formed of two plates, placed side by side, which is the opposite of the system directed by most Minutes of Specification. The rails made at the above mentioned works are in excellent repute, but they have not been long used on the great lines, and the attention of engineers has not, at present, been sufficiently directed to the subject of wear, so as to be able to determine that these rails are not liable to divide longitudinally, after a short period, like those manufactured after the same method at other foundries. We consider that the mode of manufacture employed at Hayange should not be allowed, except in particular cases. There are certain foundries where the iron is known to present great facilities for welding, but even then the manufacturer should be subjected to the strictest *surveillance*, for iron which welds easily cannot be finished properly, unless the temperature of the furnace is sufficiently high, and the rolling cylinders perform their work efficiently; we are confirmed in our opinion by many experienced engineers whom we have consulted on the subject.

The Minutes of Specification do not usually tolerate a variation of two millimetres (0·078 inch) in the length of the rails; but M. Senez, Engineer of Mines, who is commissioned to receive the rails for several companies at the Decazeville foundry, considers it impossible for the workmen to keep within these limits, and recommends five millimetres (0·196 inch) to be allowed.

It is important to examine how far the opinion of M. Senez is well founded, and whether it is proper to modify this minute, in the specifications, since they

ought not to contain any conditions that cannot be fulfilled, or that are too onerous for the manufacturer to undertake.

The practice of boring the holes for the trenails in an oblique direction (to the length of the sleeper), as on the South Eastern Railway, has been adopted on the line from Orleans to Vierzon, on the Amiens to Boulogne, and the Hazebrouck to Tampoux; wooden pins are also made use of on the line from Montereau to Troyes.



The bottom parts of the new chairs are generally hollowed out, as represented in the cut, which is a section of a chair of the Hazebrouck Railway.

The bases of the chairs on the line from Orleans to Vierzon, on the Amiens to Boulogne, and on the Hazebrouck Railway, are formed of the inclination required by the rail towards the axis of the way.

The switches employed at the present time are almost invariably formed after the plan of those on the Orleans Railway, and represented in Plate 22. The note by M. Meyer, which will be found among the Documents, supplies all the requisite information for setting up the apparatus.

An English model is generally adopted at the present time for turn-tables under 4^m 20 (13 feet 9 inches) in diameter, similar to the larger turn-table shown on Plate 27, in use on the London and Birmingham Railway. The only difference made in new turn-tables consists in casting the lower plate of the turntable in one piece, which renders it less subject to derangement.

Turn-plates formed with columns are also used after the plan described in Plates 28 and 36.

Turn-tables of larger diameter are constructed after different models, as shown in Plates 26, 28, and 31.

CHAPTER I.

OF THE LAND REQUIRED FOR THE ESTABLISHMENT OF A RAILWAY.

THE first question to be resolved on undertaking the construction of a Railway is the extent of land required for its several parts. We have first to determine carefully the plan and section of the line, and upon the same being accomplished, the width of the way, both in cuttings and on embankments, remains to be fixed, and the ground required for contingent works;—the inclination requisite for the slopes in the cuttings and on embankments also has to be decided;—the size of the ditches to be dug, and the pathway to be left between the top of the slopes in cuttings or the bottom thereof in embankments, and the fencing to separate the Railway from the adjacent property;—the span and height of bridges and tunnels;—the breadth of base to be given to the earthworks in different soils;—the extent of the terminal and intermediate stations, and also of the goods depôts;—the space required for workshops or magazines, and for the yards belonging to them.

The least error committed in the calculation of the area required by the several parts of a Railway will occasionally give rise to considerable increase in the expenditure, since any small portions of land required for subsequent enlargement always cost far more in proportion than the original strip purchased.

In making our calculation of the land required for a Railway, and in taking out the cubic contents of the earthworks, we must always remember that the line representing the Railway in the longitudinal sections commonly refers to the level of the rails, and that the ballasting on which the way is laid is generally 0^{m} 50 to 0^{m} 60 (1 foot 8 inches to 2 feet thick).

SECT. I.—*Gauge of Way and Width between the Rails.*

The total width of the road on embankments consists of the spaces required for the two lines of way; the space between them, and the two spaces on the out-

B

side of each. The same widths are required in the cuttings, together with the ground necessary for the ditches.

The gauge of way of all the Railways employed in the conveyance of passengers in France and Belgium, and of the greater part of those in England, is 1^m 44 (4 feet 8½ inches), measuring from the face of one rail to that in connexion with it; or 1^m 50 (4 feet 11 inches) from centre to centre of the rails.

The gauge is a little wider on the Eastern Counties Railway; taken from the interior, it is 1^m 52 (5 feet).* It is extended, on the line from Dundee to Arbroath, in Scotland, to 1^m 68 (5 feet 6 inches). On the Irish lines and railways in Russia—as that from St. Petersburgh to Zarcoe Selo—it is increased to 1^m 83 (6 feet). On those of Holland, to 1^m 93 (6 feet 4 inches); and lastly, Mr. Brunel, jun., has adopted a gauge 2^m 13 (7 feet), from inside to inside, on the Great Western Railway, or an addition of one half the usual gauge, or 1^m 44 (4 feet 8½ inches).

The principal object in increasing the width of gauge is to secure a means of constructing larger locomotives, with wheels of greater diameter, and with more powerful boilers, so as, consequently, to be capable of acquiring greater speed. It is a well-known fact, that, comparing the engines in present use, the speed of those on the Great Western exceeds the average rate of the whole of those on the remaining English Railways. We have often travelled on this line, and the rate of transit, of which we made notes, exceeded that of most of the other English lines by about a fourth. It has been at the rate of 10 or 12 leagues (24 to 29 miles); while on the other lines it was only 8 or 9 leagues (19 to 21¾ miles) per hour. But the locomotives employed on the ordinary gauge have not yet attained their maximum rate of velocity, although the surface exposed to the action of the fire has been considerably increased, but it is susceptible of still further augmentation; hence there is a possibility of constructing engines capable of transporting considerable loads without altering the width between the rails, and to acquire with these loads the greatest velocity which the resistance of the air will permit. The utility of increasing the gauge is not, therefore, sufficiently proved by our present experience; and admitting that it offers some advantages, and, among others, that of allowing a greater velocity, we should still have to inquire, what ratio these advantages bear to the additional expenditure incurred in the construction of the line. It will be readily perceived that the solution of this question would be influenced by the locality. Speed is more or less important

* The gauge of way of the Eastern Counties Railway has been since altered to the original standard of 4 feet 8½ inches.—*Tr.*

according to the demands of trade in each particular district; and it must not be forgotten that these necessities are constantly on the advance. It is a matter of regret at the present time, that many of the canals in England are established on too small a scale, although sufficient for the purpose at the original date of their construction. Some manufacturers of locomotive engines seem to favour an increase of gauge, from a belief that the several parts of the machinery would have more room, and that greater facility would be afforded both in their construction and maintenance; but their claims do not appear to us well founded, for when the several parts of the machines now in use are well arranged, they may be inspected and repaired without any difficulty; besides, any difficulty of this kind must be removed from the constant introduction of more simple mechanism, and especially those recently invented by the talented Robert Stephenson.

M. de Ridder is constructing, at the present time, an economical line of railway from Ghent to Antwerp, with one pair of rails only 1^{m} 10 wide (3 feet 7 inches). The line may be classed as second rate with respect to the amount of traffic.* The classification of railways according to their importance, as is done with ordinary roads and canals, appears to us to be the proper course, and making them of large or small sections accordingly, as in the case of canals.

The space between the rails on most of the French and Belgian lines is 1^{m} 80 (5 feet 11 inches); on the London and Birmingham line, 1^{m} 92 (6 feet 4 inches); on the Great Western, 1^{m} 87 (6 feet 2 inches); on the line from Brussels to Mons 2^{m} 50 (8 feet 3 inches). The space between the rails should be calculated to allow of the trains on each line passing each other, and leaving sufficient space between the bodies of the carriages to permit of foot passengers remaining, uninjured, between them, and for the passengers in the carriages to put their heads out of the windows without striking each other.

The distance between the bodies of the carriages on the Versailles line, left bank, is 0^{m} 84 (2 feet 9 inches), and 0^{m} 45 (1 foot 6 inches) between the footpath. A man situated in the middle space between the rails, should be able, strictly speaking, to stand upright during the passing of two trains without being injured, but the space between the rails and the width of the carriages have not been taken into the calculation (as we suppose) in this allowance, for there is reason to believe that a foot passenger in this critical situation could only save his life, if he had sufficient presence of mind, by throwing himself upon the ground.

* The locomotives on this line do not weigh, with their tenders, more than 5 tons. The wagons are also very light, with small springs, weighing no more than 13 kilogrammes each ($28\frac{1}{2}$ lbs.); but they are found sufficiently strong.

We believe that we have given the carriages on the Versailles line (left bank) the greatest width that is practicable with a gauge of 1^m 50 (4 feet 11 inches), and the interspace of 1^m 80 (6 feet) between the two lines is found sufficient; but we must remember not to reduce this space by placing small columns in the middle of it, between the lines of rails, for the support of timber bridges, which is sometimes done. The engineer and guard of one of the trains were killed on the line of the Versailles Railway (left bank) by striking their heads against columns so placed.

If the width between the rails is extended to 2^m 50 (8 feet 3 inches), on the line from Brussels to Mons, it will be for the purpose of obtaining a ready means of increasing the gauge, as we have been informed. The middle space being only 1^m 0 (3 feet 3 inches) on the Railway from St. Stephens to Lyons, the Directors have found themselves much restricted in the construction of the carriages, and have been obliged to increase them in length instead of in their width, in order that the bodies of the carriages of two meeting trains may be enabled to pass each other.

On the Liverpool and Manchester Railway, which was made about the same time as that from St. Stephens to Lyons, this middle space is greater, being 1^m 55 (5 feet 1 inch) wide, but experience has shown that even this width is insufficient; it is consequently increased on all lines of importance recently constructed to 1^m 80 (5 feet 10 inches), or 1^m 90 (6 feet 3 inches).

In respect to the extent of the side spaces, these vary like the inclination of the slopes, according to the nature of the soil. They should be increased in proportion as the soil on which the road is laid deteriorates in quality.

We observe the following rule is laid down in English specifications. Upon embankments on ordinary soils the side spaces are 0^m 50 (1 foot 8 inches) wider than in the cuttings, but when the soil is marshy, they are on the contrary widest in the cuttings. In certain soils of this kind they are 3^m (9 feet 9 inches) in cuttings, 1^m 50 (4 feet 11 inches) to 2^m (6 feet 6 inches) on embankments.

This width is necessary, lest the vibration occasioned by the motion of the trains should produce any slips in the earth; or in the event of any slips taking place, the road would be less likely to be buried and thrown out of order.

On the Versailles line (left bank) the side space in the cuttings is 0^m 87 (2 feet 10 inches) in good soil, comprising the distance between the outside of the rail and the side of the ditch, and on embankments 1^m 57 (5 feet 2 inches) or 0^m 90 (3 feet) for cuttings, and 1^m 60 (5 feet 3 inches) for embankments measuring from the centre of the rails.

The distance on the Great Western from the outside of the rail and the edge of the embankment, or to that of the ditch, is 1^m 45 (4 feet 9 inches) on ordinary soils. On the line from Liverpool to Manchester 1^m 52 (5 feet); on the London and Birmingham 2^m 20 (7 feet 2 inches); on the new Belgian lines—as that from Brussels to Mons—it is 1^m 75 (5 feet 9 inches).

The width of the side spaces on the Versailles line (left bank) appear to be too little, especially in the cuttings. We think the width ought not to have been less than 1^m 50 (4 feet 11 inches) and that it would conduce to the advantage of the Railway and the safety of the traffic to increase it.

The side spaces are diminished in tunnels, and sometimes in other works, in order to lessen the expense. The water is then carried off by a drain, or conduit, placed between the rails (see Plates 17 and 29, First Series, Railway Practice). In cases where there is no reason to fear the water from without, the drains may be omitted.*

We must, however, recollect that too great a reduction of the side spaces in the tunnels may expose the passengers to serious accidents.

The "Administration of Bridges and Highways" state that the width of the side spaces of Railways shall be 1^m (3 feet 3 inches) in the cuttings, in tunnels and on bridges, measuring from the extreme edge of the rail to the exterior edge of the road, and 1^m 50 (4 feet 11 inches) on embankments.†

The width and generally all the other dimensions of the ditches must be proportionate to the quantity of water they are subject to receive.

In deep and extensive cuttings, the ditches not only receive the water flowing along the road, but also that arising from the slopes, which is sometimes considerable. The ditches are very difficult to maintain in such cases, and require to be of great capacity. The depth should be regulated so as to fall a little below the bottom of the ballasting forming the roadway, which ought to be kept as dry as possible.

The depth ought in general to be greater in marshy soil than in that of the ordinary character, in order to give height to the dry portions separating the road from the humid soil, for the rails will be exposed to perpetual derangement if the vibrations arising from the trains are transmitted to the latter. We shall allude hereafter, in treating of the construction of the roadway, to the manner in which we succeeded in crossing a swampy soil of the worst character on the

* The invert and drain is omitted in some of the tunnels on the Birmingham Railway.—*Tr.*

† This term in the specification doubtless refers to the edges which border the ditches in cuttings, but it is not clearly defined.

Versailles Railway (left bank) by the adoption of a peculiar system of draining with deep ditches.

The dimensions of the ditches in a deep cutting on the Versailles line (left bank), called the Clamart cutting, are 0^m 90 (3 feet) wide at the top, 0^m 24 (9 inches) at the bottom, and 0^m 60 (2 feet) deep. A wall formed of dry stones borders the ditch at the side of the road, and is inclined in the ratio of one-tenth of base to one in height; the slope of the opposite side of the ditch is cut in the soil and inclined in the ratio of one of base to one in height. This cutting, being 1700 metres long (1859 yards) with a maximum depth of 16^m 86 (55 feet 3 inches) these dimensions have been found insufficient.

The ditches require to be emptied when they become filled, and as often as their situation permits of. There are four absorbing wells or tanks dug in the great cutting of Clamart, and disposed along the line. By increasing the number of these wells they have been enabled to remedy the deficiency in size of the ditches, which are thereby kept of moderate dimensions. The ground in the vicinity of Paris is admirably adapted, by the nature of the strata composing it, for the formation of absorbing wells. All soils, however, do not possess this quality.

It is of the highest importance, generally speaking, to preserve, by every means, the whole of the works of a railway from contact with water, especially the road, whether arising from springs or rains. No expense should be spared to secure this object, and we propose to explain hereafter the means by which this object may be attained.

On embankments, the water which flows from the road nearly always runs down the face of the slopes; if there are any ditches, they are placed at the foot, and generally only upon that side where the water, running from any sloping ground, might tend to wash away the base of the embankments.

There are parapets raised on each side of the embankments on some railways, as the Liverpool and Manchester and the Grand Junction, to prevent, as far as possible, the fall of the locomotives over the banks, in the event of their getting off the rails, and to break the force of the falls, in which cases drains are dug on the embankments, by the side of the parapets, which empty themselves at regular distances, through openings made in the latter.

We cannot furnish any other guide for the calculation of the other dimensions of the ditches skirting the feet of embankments, than that they should be proportioned to the volume of water they have to carry off.

The open ditches at the base of the embankment on the Versailles line (left

bank) ought, according to the specifications transmitted to the principal contractor of the line, to be 1^m 60 (5 feet 3 inches) at the top, 0^m 30 (12 inches) at the bottom, and 0^m 50 (20 inches) in depth.

The sides of the embankments having received the requisite inclination, a path of 1^m (3 feet 3 inches) appears to us sufficient for the purposes of communication along it, and for protecting the adjacent property from any fall of stones which might happen to get detached from the embankments.

M. Seguin, sen., in his Work on Railways,* expresses his opinion as follows, respecting the quantity of land that companies should purchase along extensive cuttings.

"It is indispensable that the Company should be proprietors of a strip of land on each side of extensive cuttings throughout their entire length, for a width of 2 or 3 metres (6 feet 7 inches to 10 feet 9 inches) or more if necessary. This space is reserved to construct a ditch to carry off the water, and should be attended to with the greatest care, for it may be readily perceived that a stream of water flowing along a length of 12, 15, or 20 metres (13, 16, or 22 yards) is quite sufficient to wear away and channel the soil, choke up the ditches below the road, and cause slips, and consequently accidents. The Company ought also to obtain, especially when it can be acquired at a small cost, all the land above the cuttings which may be inclined to slip; for sometimes, whether through ill will, ignorance, or real necessity, the owners thereof being masters in their own right, cause any kind of works to be constructed thereon, without concerning themselves whether the same are liable to be destroyed by the works of the Railway, and in case of such accidents as the loss of their land and works occurring, the arbitrators will not fail (they may well expect) to make the Company pay according to the increased value their property has acquired by the opening of the new channel of communication."

"The ditches connected with extensive cuttings should be considerably increased in capacity at the upper side; both the width and depth necessarily require to be much greater in proportion as the face of the cutting becomes elevated."

SECT. II.—*Of the inclination of the slopes for cuttings and embankments.*

The rules employed to determine the inclination of the slopes for the cuttings and embankments of roads and canals, apply equally to railways. It is, however,

* "On the influence of Railroads, and on the art of planning and constructing them, by Seguin, senr.," 1 vol., Oct., 1839.

necessary to observe, that the consequences of a slip of the earth on railways are far more serious than on ordinary roads, also much more difficult to repair, and that the cost of altering the inclination of the sides of cuttings when the railroad has been opened is much more considerable. It is consequently important, in making railways, to determine the inclination of the slopes with the requisite accuracy, in order to obviate the necessity of altering them after the line is opened.

The slipping of one of the slopes in a cutting on the line from Alais to Beaucaire, occasioned the destruction of a locomotive and several wagons loaded with coal, by overwhelming them upon the line; and an accident of a similar nature on the Great Western Railway caused the death of several passengers. On the great cutting of Clamart on the Versailles line (left bank), the necessity for rectifying part of the slope after the road was opened, occasioned an outlay of double what would have sufficed if it had been done at first. The works also, unless executed by night, require redoubled vigilance on the part of the workmen to prevent accidents.

It is advisable in extensive cuttings to form a narrow platform or stage above the ditch, about 0^{m} 30 (12 inches) wide, inclined considerably in an opposite direction to the slope. (See some of the Sections of Earthwork in Plate I.) The object of this bank (*banquette*) is to prevent the small stones, &c., which become loosened from the bank, especially during the period of frost and thaw, from falling into the ditch, and obstructing its channel. It is also useful as a place to deposit the mud removed from the ditches in the process of cleansing.

It is often found necessary, at the top of high cuttings, to intercept the water by means of banks or by ditches, and prevent it running over, and injuring the surface. (See Sections of Earthwork, Plate I., which exhibits the dimensions necessary for this part.) The inclination of the slopes in cuttings varies, but within moderate limits; those of embankments are usually one and a half at the base, to one in height. When formed of soft soil, the breadth of the base is increased without that of the road itself proportionally increasing. If the inclination of these slopes should afterwards be found insufficient, they cannot be changed. When an embankment is required to be carried up to a certain height in earth, we should first ascertain what base it is necessary to give it, regard being paid to the greater or lesser degree of solidity possessed by the soil on which it has to be raised. The slopes are very flat on the London and Birmingham Railway; the slopes of all the great cuttings have a proportion of two of base to one of height, and those of the embankments have the same inclination.

The following extract from the work of M. Seguin, senior, already cited, naturally presents itself after the observations we have just made on the inclination to be given to the slopes of cuttings and embankments.

" It is hardly possible to determine beforehand what angle is best for the cuttings, in order to prevent the occurrence of slips. There are certain soils which stand perfectly well at an angle of 45°, and others which crumble down at a much less angle, on account of their being mixed with beds of clay, and moistened by underground springs, &c."

" The lower sides of cuttings are generally more solid than the upper, because they are always free from water. From the uncertainty respecting the angle under which the slopes are best sustained, and for the sake of expedition, the slope is sometimes left to time and the influence of the rain and frost, to form, when it takes a natural angle according to the nature of the soil. The workmen are directed to throw up the soil from the ditches as fast as it slips. We have found this method succeed when the soil in the cuttings has been sandy, or full of loose stones, and adapted to form a foundation for the road; but we have remarked that when movements take place in vegetable soils, the slips of earth occur with great irregularity, and the slopes, in place of taking an inclination favourable to their stability, as might be expected, the result of a natural movement, assume, on the contrary, a form the most unfavourable for stability. The upper parts always remain standing perpendicular. The slip at E buries itself in the middle of the cutting, the base A is set in motion, when it becomes necessary to excavate much more of the soil, and even then the slopes never stand so regular or so solid as when it is cut at first to a suitable form."

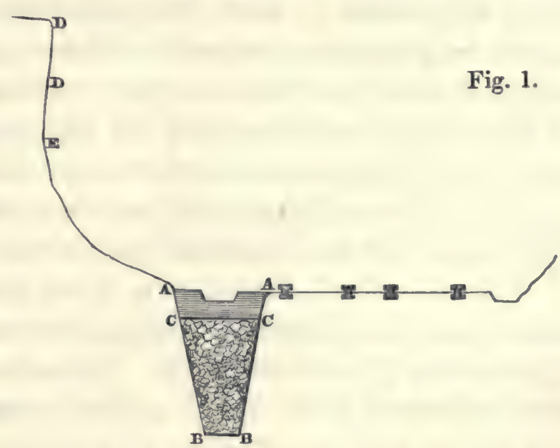


Fig. 1.

" The slope requisite to be given to cuttings is determined, not only by the nature of the soil, but also by its position with respect to height. If an excavation is made on an elevated portion of land at its crest or highest part, a greater inclina-

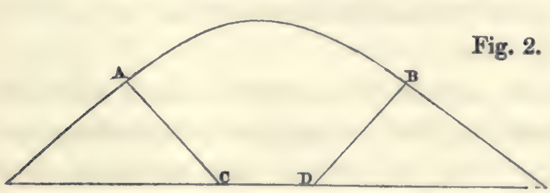


Fig. 2.

tion can be given to the slopes than usual, since there is no reason to fear the presence of water above, either from floods or springs. But if the cutting should pass through the side of the hill, it will be necessary to calculate the inclination accurately, and to make the slopes sufficiently flat to secure the works from the chance of subsequent accidents and interruptions. We should also be on our guard, and provide against the slipping of any masses of earth situated at the upper sides of extensive cuttings, and which under certain angles have a constant tendency to descend into the cutting, together with the water arising from rain or springs, with which they may be charged. The opening of the cutting often occasions the running of streams, and which at length reach any beds of clay that may exist, and sooner or later cause slips."

"The local nature of the climate in the vicinity of a railway ought also to be taken into consideration, and viewing the subject in reference to this point, the southern parts are much less advantageous than the northern. In the high and mountainous districts of the south more especially, we may expect to meet with frequent interruption, as the works are exposed to the twofold influence of opposite climates.

"The Railway from St. Stephens to Lyons is elevated at its upper extremity, 500^{m} (546 yards) above the level of the sea. Now, it is known that on an average an elevation of 160^{m} (175 yards) gives a difference equivalent to one degree in temperature, and answers to a distance of 56 leagues, ($135\frac{3}{4}$ miles) further northwards, within the limits comprised, or between 30 and 60 degrees of latitude. The works have therefore to resist the influence of cold equal to a climate 200 leagues ($484\frac{1}{2}$ miles) further north than our part of the country, while they are also liable to all the damage which may result from storms of rain, and the overflowing of torrents, &c. so common in southern climates."

The work of M. Minard, "On Works for the Navigation of Rivers and Canals," contains an excellent chapter on extensive cuttings, and the inclination requisite to be given to the slopes. The author reviews the different slopes by which the various kinds of soil are best sustained, and he enters into details, which are too long for quotation, for which reason we must refer our readers to the work itself.

Some hints on the angles under which various soils are sustained will be found in Brees' "First Series of Railway Practice."

It must not be forgotten, whatever angle may be adopted, that a soil which will stand with a slope of great inclination before being exposed to the changes of the atmosphere, may possibly give way when subjected to their influence. This

is more particularly the case with certain schistes which are much affected by exposure to the air.

Sect. III.—*Of the Span and Height of Bridges.*

The Articles 9 and 10 in the Specifications of the Railway from Paris to Rouen, which were copied exactly from those of the Railways from Orleans and from Strasbourg to Basle, fix the dimensions of bridges on railways as follows:

" When the railway passes over a highway (*route royale*), or a district road (*route departamentale*), or over an internal line of communication (*chemin vicinal*), the span of the bridge is not to be less than 8^m (26 feet 3 inches) for a highway (*route royale*); 7^m (23 feet) for a district road (*route departamentale*); 5^m (16 feet 5 inches) for an important internal communication (*chemin vicinal*); and 4^m (13 feet 1 inch) for ordinary ones. The height from the roadway to the keystone must be 5^m (16 feet 5 inches) at least. The height to the beams of timber bridges must be at least 4^m 30 (14 feet 1 inch); the width between the parapets must be at least 7^m 40 (24 feet 3 inches); and the height of these parapets 0^m 80 (2 feet 7 inches.)"

" When the railway passes under a highway or district road (*route royale ou departamentale*), or an internal communication (*chemin vicinal*), the width between the parapets of the bridge which support the road must be fixed at 8^m (26 feet 3 inches) for a highway (*route royale*), 7^m (23 feet) for a district road (*route departamentale*), and 5^m (16 feet 5 inches) for an important internal communication, and 4^m (13 feet 1 inch) for an ordinary one. The span of the bridges between the piers must be at least 7^m 40 (24 feet 3 inches), and the vertical distance between the rails and the intrados must not be less than 4^m 30 (14 feet 1 inch)."

The 13th article fixes the slopes of approaches of the neighbouring roads and thoroughfares (*routes et chemins vicinaux*). By the assistance of which, and the preceding, we can calculate the surface of land necessary to be purchased for the alteration of the different roads to be lowered or raised.

This article may be rendered as follows:—

" When it is necessary to alter the present routes, the inclination of the slopes of approach for the deviations must not exceed 0^m 3 centimetres per metre (1 in 33) for the highway and district roads (*routes royale et departamentale*), and 5 centimetres per metre (1 in 20) for the neighbouring routes of internal communication (*chemins vicinaux*)."

"The Companies are at all times at liberty to suggest any departure from the preceding rule with regard to the lines of internal communication."

The breadth between the walls of bridges under Railways is fixed by the same specifications at 7^m 40 (24 feet 3 inches), and the height beneath the key-stone at 5^m 50 (18 feet).

With respect to the height of the bridges built over the Railway, we conceive that they should be sufficient to allow of the tallest passenger standing upright on the imperial of the highest carriage with his hat on, as the train is proceeding. We have seen passengers, occupying the outside places on the Versailles Railway (right bank), rashly stand up during the passage of the trains. They would have inevitably been killed if the bridges on this line had not been of great height above the rails.

The height of the bridges on the line of the left bank being of smaller size, we have raised a kind of covering over the seats of the imperial, not, as some imagine, to shelter the passengers from the rain and sun, but to prevent their standing upright. The highest carriages are 2^m 80 (9 feet 2 inches) high, and if we take the height of the tallest traveller, with his hat on, at 2^m 20 (7 feet 3 inches), we shall find that the distance from the rails to the intrados of the arch in stone bridges, or to the cross-beams in timber bridges, must be at least 5^m 0 (16 feet 5 inches).

It is not only for the sake of obtaining the means of placing seats on the imperials and to prevent accidents that it is necessary to give such a great height to the bridges constructed over a Railway, but also for the convenience of taking diligences, fully equipped and loaded, on the Railway-trucks.

CHAPTER II.

OF THE EARTHWORKS.

It is an acknowledged principle that Railways intended to afford the highest rate of velocity to the trains should fulfil, as near as possible, the two following conditions, unless the amount of profit to be derived does not warrant the necessary outlay in accomplishing them. First, they should present gradients of the slightest inclination; and, Secondly, curves of large radius only.

If, therefore, the gradients on ordinary lines are considered equal to $\frac{5}{1000}$, then on those where the highest velocity is employed they should rarely exceed $\frac{1}{1000}$. It is also only at certain points on the great lines of railway that the engines are necessitated to proceed at reduced velocity. Curves of less than 500^{m} (546 yards) radius are therefore generally to be found near the extremities of a railway;* the turns on ordinary roads and canals are, however, both sharp and frequent.

It is impossible to fulfil the before-mentioned conditions in many localities, except by incurring a vast amount of earth and other extensive works, by opening deep cuttings through the hills, or driving long tunnels and traversing the valleys by enormous embankments or by gigantic viaducts, in order to form the line.

The earthworks on Railways are of far greater importance than those occurring in the making of ordinary roads and canals, and cannot be executed with the requisite economy and despatch, without employing new modes of construction. The railway itself has afforded the requisite assistance, temporary rails being laid down to convey the soil arising from the cuttings proceeding at other parts of the line, and even the steam-engine employed on these temporary lines to convey the wagons when the distances of transport are great. The method of construction requires important modification when applied to extensive viaducts, but which are trifling compared with the new systems applied upon the earthworks.

We have executed earthworks on the Versailles Railway (right bank) by

* The line from Newcastle to Carlisle forms an exception to this rule. A very great number of curves of small radii (about 400 yards) being formed along it, so that the trains cannot proceed with great speed, and the maintenance of the way and material is rendered very expensive.

means of self-acting planes (*plans automoteurs*) and locomotive engines, with greater rapidity, to the best of our knowledge, than has been attained with any other works of a similar nature, but it has been at an increased expense. The conveyance of earth on the Belgian lines is effected by means of rails laid down at less expense, but also attended with far less despatch.

The arrangement of large workings along the lines for the execution of the earthworks varies according to the degree of economy or despatch regulating the views of the Directors, and numerous other circumstances, which our readers may readily imagine without our detailing them.

This constitutes a distinct art, with which we are too imperfectly acquainted, but much useful information on this subject may be found in the work of M. Etzel, already quoted.*

We shall limit our remarks in this chapter to the precautions necessary to be taken to sustain the slopes of deep cuttings, and to prevent the occurrence of slips in extensive earthworks.

SECT. I.—*Means to Prevent the Occurrence of Slips of the Side Slopes of Deep Cuttings.*

The slopes of cuttings present a large surface. It is always found necessary, in order to prevent their slipping, to drain away the water, either by means of open ditches dug along the surface of the soil, by drains filled with broken stones, by means of conduits constructed of masonry, or by parapets. (See Sections of Earthworks, Plate I.) If there is reason to suppose that the water which collects behind the parapet will find its way beneath to the cutting, by penetrating the soil, it will be necessary to open passages at certain distances in the parapets, corresponding to the stone drains laid along the cutting. Small banks (*banquettes*) are also carried along, at different heights, to prevent the wearing down of slopes of great elevation, and on these banks ditches are made, which empty themselves in those bordering the road by sloping gutters.

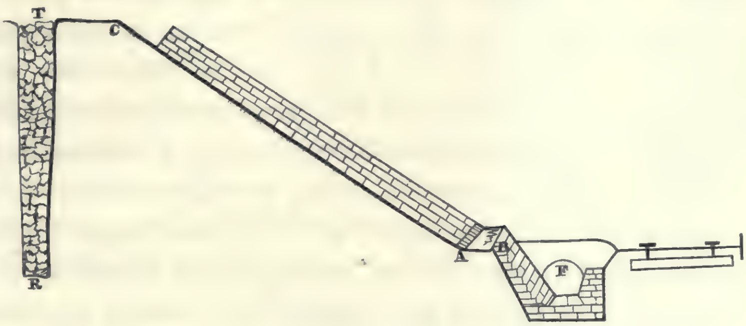
A review of the various means which have been employed both to drain and support the slopes of deep cuttings does not form part of our design. We shall limit ourselves to describing those which M. Delaserre, Engineer of bridges and roads, has successfully employed on the Versailles Railway (left bank) to prevent the slipping of the upper portion of the bank, of cuttings made in a sandy clay soil, and to point out the process followed under similar circumstances in the

* See Introduction to these notes.

canal of St. Maur on the Belgian line, and on the line from St. Stephens to Lyons. We will also state how Mr. George Stephenson succeeded in opening cuttings of great depth through marshy soils on the Liverpool and Manchester Railway.

A cutting through a soil consisting of sandy loam on the Versailles Railway (left bank) was found very difficult to execute, near Sevres. It became continually filled up by slips from the upper portion of the bank, which were dragged down from the effects of water.

In order to drain this cutting, M. Delaserre constructed at the base near the ditch, a small bank (*banquette*) AB, inclined in a contrary direction to the face of the great slope as shown by the figure; and on this bank he raised a wall of dry stones, the whole height of the cutting, whose exterior surface was inclined at an angle of 1^m 50 (4 feet 11 inches) to 1^m (3 feet 3 inches.) The water passing from above runs between the



stones of this wall, and flows partly into the ditch, partly into the angle A, comprised between the slope A C and the bank (*banquette*) A B. Small channels empty the water collected at A into the ditch F, a slight inclination is given to the surface of the *banquette* at the angle A towards these channels to facilitate their flow. Thus the water which might overflow the slope A C being, as it were, absorbed by the wall of dry stones, cannot wear it away, and the earth of the slope is sustained by the weight of the wall.

The thickness of this dry stone wall varies even in the same cutting with the nature of the soil; buttresses, or counterforts, are placed opposite the most considerable springs.

In other cuttings on the same line, they have constructed several *banquettes* receding on the side slopes, and which support the stone walls, which are formed of the same thickness throughout. At certain points where there was reason to doubt of the solidity of the bottom of the ditch, they constructed small arches over it, as shown in the cut.

They gave the bank (*banquette*) originally supporting the dry stone wall, a slight fall towards the ditch in the same direction as the inclination of the slopes. This ledge is 2^m (6 feet 6 inches) wide. The wall of dry stone serving for a

drain was only 0^m 20 (8 inches) in thickness. It was covered over with a thin layer of puddled clay, and another of rammed earth of sufficient thickness, but the water, accumulated in the drain on account of its being too narrow, flowed over on to the banquette and injured the slopes.

They then inclined the banquette in a contrary direction, increased the thickness of the wall, and removed the layer of puddled clay, but preserved the bed of rammed earth, which further experience soon led them also to take away. We have extracted the following details from the Annals of bridges and roads:

"The following method was employed on the Canal of St. Maur, to remedy the effect produced by the waters which were breaking down the banks on each side. A drain, T R, was formed parallel with the cutting, and of the same depth, which emptied itself at its extremities. It appears to us that the construction of this drain would be found more expensive under some circumstances than a dry stone wall placed on the face of the slope. (See cut, p. 15.) It is self-evident, although we have represented each method of draining by one figure only, that it is never necessary to employ both at the same time.

We read in the last report laid before the Belgian Chambers by the Minister of Public Works, the following passage on the difficulties encountered in making a cutting on the railway from Courtrai to Mouscron, and on the methods employed in surmounting them:

"It was observed at the commencement of the year 1841, that the banks of a portion of a cutting made at Lauwe, which, however, was hardly an average depth of 2^m 0 (6 feet 6 inches), would not stand under the inclination given to them. The waters collected by the mountain which was cut beneath by the railway, were continually flowing and channeling out fissures in the soil situated in the rear of the cutting. These increased more and more, and undermined the slopes of the cutting. The soil slipped away in successive vertical layers, and the earth thus shaken acquired such a degree of moisture, that it appeared impossible to replace it at any angle."

Effects similar to these, but of less importance, viewed in reference to the height of the cutting, have been in many instances successfully combated, especially in the case of the Wilmerson cutting, near Tirlemont, where by employing cradles full of stones or fascines the result was most successful.

The engineer determined, in the month of August, 1841, to make a trial of some works of this kind in the cutting of Lauwe, and which were attended with equal success, for this section of the line having been reconstructed in 1841, it has been found that the portion formed with cradling has preserved its soundness up to this date, May, 1842, notwithstanding the rain and frost, while the remain-

ing portion of the cutting has been entirely filled up by slips of the earth; the land situated behind it has also sunk away to a great extent.

On another railway in Belgium, a course for the waters was opened through thin layers of clay by perpendicular borings.

" There are certain descriptions of soil," says M. Seguin, senior, " more susceptible than others to absorb and maintain humidity, and which in rainy seasons wear away, and become transformed into mud, and are then apt to fall to the bottom of the slopes. When this is the case, it is necessary to supply channels to lead off the water, by giving it issues sufficiently deep, that the pressure of the water should be sufficient to cause it to filter away through the soil. The following is a method which I have employed with the greatest success."

"I had a ditch dug at the base of the slope, in the dry season, A B, 3^m (9 feet 9 inches) deep. I had the entire space, B C, filled with stones, arranged by hand, and covered from C to A with clay, in order to prevent the water of the ditch flowing on this bed and depositing any earthy particles in the interstices of the mass of stones. (The latter obtained the name of *pierelle* in the locality where it was used.)"

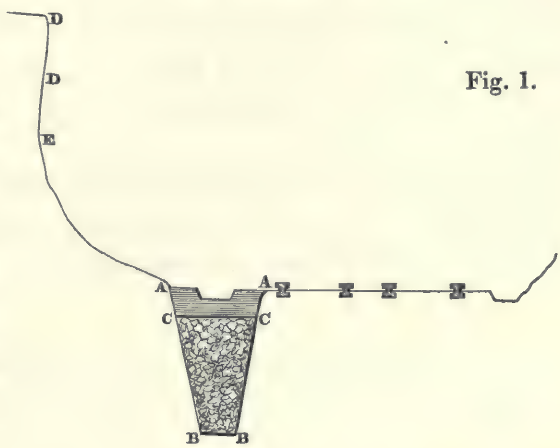
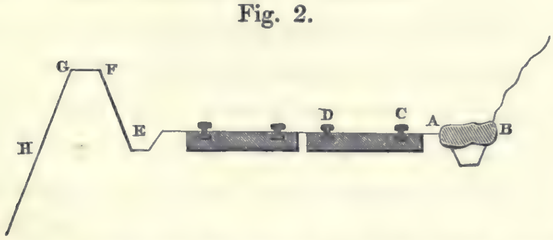


Fig. 1.

" This expedient is sufficient to drain the upper portion of the cutting effectually, and gives the shrubs and vegetation time to cover it, which has consolidated and secured the soil for ever."

Fig. 2.



" We may also place slabs of stone, A B, at intervals, near those points where we anticipate any movement of the earth, in order to maintain the feet of the slopes, which should be very strong and sound. The slabs press on the ballasting on one side, and the slope on the other, and form a kind of arch over the ditch. This arrangement has also the advantage of protecting the bank AC, which ought always to be better supported than the road CD, because

the flanges of the wheels tend to preserve the latter, by pressing against the rails. These present an insurmountable obstacle to the rails approaching each other, while a multitude of causes tend to push them outwards, and to enlarge the breadth of the road."

The following method was adopted by the celebrated Mr. George Stephenson (whose son, Robert Stephenson, is no less distinguished) in forming the cuttings through the Chat-moss bog on the Liverpool and Manchester Railway, some parts of which are nine feet deep. The depth of the marshy soil above the clay, which formed the substratum, varied from 10 to 34 feet, and was so soft that animals were unable to pass over it.

The cutting was commenced by digging on either side of the railway two ditches parallel to it, two feet deep ; and when, by means of these ditches, a strip of the upper portion of the marsh became drained, they excavated the earth by the usual method, from 12 or 15 inches deep, and then deepening the ditches, they removed a new layer until they reached the level required for the base of the railway.

The draining of the marsh was facilitated by some portions of the railway being situated above the level of the surrounding land, which was the only circumstance which favoured the undertaking.

Sect. II.—*Of the Construction of Large Embankments, and the method of preventing their slipping or rolling down.*

It is considered desirable, in laying out plans for roads and canals, to compose the cuttings and embankments in such a manner that their contents are equalized as much as possible, and consequently so that the soil removed from one should serve to form the other. From our experience of railways, we find that this plan is not always suitable; since it cannot be adopted, in some cases, without making the embankments excessively high, and expensive in the construction and maintenance; or, on the other hand, the cuttings will be difficult to excavate, or at least to drain. In other cases, the earth would have to be conveyed to long distances, and a great increase of expense would be the result, not only on account of the length of the lead, but also from the delay which would occur in the completion of the line.

The capital required in the construction of a railway is so considerable in its early stages, that too much despatch can hardly be used to render the same productive.

It is moreover of the highest importance that the extensive embankments so frequent on railways should be as rarely as possible composed of clayey soils, as we shall explain hereafter, and of still greater moment that they should not be laid upon swampy soils; yet, in point of fact, it is seldom that both of these evils can be avoided, and the embankments made to compensate the cuttings.

We dwell upon these points, in order that it may become evident, notwithstanding the analogy which appears to exist between the earthworks of roads and canals and those of railways, that there is a palpable difference in the method employed in executing them.

The method of spoil banks and side cuttings is much more frequently adopted in making railways than in other works of communication.

They are very generally used on the English railways, the Belgian, and those in the environs of Paris. The excavations which may be seen bordering many of these embankments, and which have unfortunately become converted into pools of unwholesome and stagnant water, sufficiently denote their origin.

On the line from Basle to Strasbourg, almost all the embankments have been executed by means of side cuttings; but they have not formed these excavations of such a depth as to prevent the soil being used for the purposes of agriculture; a portion of the vegetable soil was first deposited at the sides, and afterwards returned to the surface.

On the Versailles Railway (left bank), the quarries bordering the line have furnished materials for the formation of some of the filling, without expense to the works; the proprietors of these quarries have even supported a part of the expense of the transport from the quarry to the rails.

After the period of the Belgian report, which we have before quoted, an important portion of the line from Courtrai to Mouscron was being executed by means of wagons; but, alarmed by the tardiness in the conveyance of the earth, the managers had recourse to the method of spoil banks and side cuttings, and have had every reason to congratulate themselves upon the result, for the earth arising out of the cuttings proved to be of the worst character possible, whereas that employed for the embankments is of the best description.

The embankments for ordinary roads and canals are generally raised in successive layers. They are sometimes rammed, and are in all cases compressed by the wheels of the wagons and the feet of the horses.

It would be too long and expensive a process to raise the extensive embankments on railways by layers of earth rammed down, or even simply compressed by means of the carts and horses.

The formation of railway embankments proceeds *en masse* the whole height intended, except in particular instances; thus the embankment is commenced next the cutting, and a small portion finished to its full height, by discharging the earth from the cutting in the line of the intended work; they then move the rails forward, and continue to deposit the soil at the head of the embankment as before, until it is again level with the top. It is only by proceeding in this manner that rails can be employed for the conveyance of the soil, and they are laid down on the embankment as the latter becomes extended. The earth wagons are drawn up and tipped at the extremity of the rails, which reach to the head of the embankment.

We allude, in the present instance, to embankments of great height and considerable length; for when the earth required for an embankment has to be carried a short distance only, it is often more economical to employ ordinary carts in preference to railway wagons.

Earthwork executed by means of carts is also more dense and less subject to settle than when formed by wagons; nevertheless, we must admit, that if we were called upon to determine the mode of conveyance, the use of carts, on certain lands, becomes next to impossible, after heavy rains, while the working of wagons suffers no interruption.

Where embankments are constructed of great height, in connexion with and surrounding constructive works, if carried on with much haste, the masonry will frequently split, shrink, and settle. They require, therefore, to be executed with the greatest care, and to be well supported on all sides by arches formed of masonry, and spread uniformly on these arches in layers of about 15 centimetres (6 inches) deep, well rammed.

When large embankments are formed on soils capable of compression, it is necessary to use similar precautions in order to avoid bursting the soil, by compressing and loading certain parts with too great weight. It is as well, also, when soils capable of compression are composed of strata which are liable to slip one over the other, to commence the embankment by conveying the earth to the lowest level, or bottom of the valley, instead of tipping it in the usual manner from the extremity of the cutting.

A serious accident of this nature took place on the Versailles Railway (left bank). In traversing the Val-Fleury, the embankment, which was required to be 30 metres high (99 feet), had not reached above 13 metres (42 feet), when the soil, composed of solid beds of chalk and clay, lying in an inclined position, became softened by the action of some currents of water, commenced cracking.

The execution of the work with wagons ought to have been immediately discontinued, but the contractor, owing to a misunderstanding with the directors of the company, did not feel bound to comply with the instructions of the engineer. The fissures in the soil consequently increased in number and size, and certain portions, which were much incumbered, gave way, while the adjacent masses, being less loaded, swelled up. In other parts the chalky soil slipped over the clay which it covered, and buildings situated at a short distance fell down. The use of wagons was therefore obliged to be discontinued, and recourse had to carts. The body of earth throughout the entire embankment was increased, commencing with the portion at the bottom of the valley, and the motion of the soil at length became almost imperceptible.

We see, notwithstanding, that even when these precautions are taken, it is impossible to prevent the earthwork giving way from the mere weight of the soil when raised above a certain height.

The most simple method of attaining the end desired, and which has been employed with complete success on other parts of this line, consists of enlarging the base of the embankment in such a manner as to reduce the pressure on the area of surface as much as the yielding nature of the soil required, and to ram the earth; but where the land round the embankment is covered with houses of great value, it becomes necessary to have recourse to other expedients.

They endeavoured to drain the soil, and render it incompressible; to attain which they dug wells and pits, and united them by subterranean canals. This operation, however, was found very difficult to accomplish effectually. The earth having already broken away in all directions, presented nearly all its former instability, and they were obliged to abandon the prosecution of the embankment for a certain time, and to replace the upper portion by timber work.

The base of the embankment, as we have above shown, may be increased either by diminishing the inclination of the sides, or by strengthening the lower part by means of a small portion of additional earthwork well rammed, with the upper face finished with a bank (*banquette*) extending along the slope of the principal embankment. See Sections of Earthwork, Plate I.

By making the inclination of the sides flat, embankments may be rendered available for all kinds of plantations. The same advantage is not obtained by adopting the second plan, but if the banquettes are not raised to a great height, the total amount of earthwork will not be much increased.

The employment of an additional embankment of support terminated above with a banquette, ought moreover to be recommended for embankments raised on

the flanks of hills as a means of sustaining them, as they are naturally inclined to slip on the sides constituting the greatest inclination.

A soil of very yielding nature, similar to that we met with on the Val-Fleury, presented itself at the bridge of Cubzac. The embankment was obliged to be constructed of material having a great number of open cavities connected with it, in order to diminish the weight of the mass.

In the execution of the Canal of Beaucaire, in Central France, they introduced a bed of fascines between the soft soil and the embankment.

Mr. George Stephenson proceeded in the following manner with the embankments raised on the swampy soil of Chat-moss, of which we have before spoken, and which were 12 feet high. Deep ditches were dug along the two sides of the line, and the earthworks were then raised on the band of earth drained by these ditches. No more than four times the quantity of earth was required than is necessary to be employed for an embankment of the same dimensions on a resisting soil.

In another moss, 20 feet deep, where the ordinary method of forming embankments had been followed, they used an amount of soil in raising an embankment of 4 feet, that would have sufficed for one of 24 feet high on solid ground.*

Therefore, whatever may be the means adopted to distribute the pressure on a soil which is subject to compression, it is essential that we should not neglect to drain it as much as possible, as we have described was attempted to be done in the Val-Fleury.

The cuttings on the Versailles Railway (left and right banks) furnished a considerable amount of sandy clay soil, which should have entered into the formation of the embankments, but it was soon found, from the nature of the soil, that it would be subject to accidents, unless constructed with proper precautions.

These precautions consist principally in the employment of certain means to preserve the clay from coming in contact with the water running over the surface of the soil, or from the rain. Clay, when undiluted, is not more subject to displacement than other soils.

M. Delaserre employed the following method of preserving argillaceous soils from the effect of rains on the line of the left bank. The slopes were covered with as thick a layer as was possible of sound earth, well rammed, which was

* The English author, from whom we have extracted this paragraph, does not say whether Mr. G. Stephenson enlarged the base of the embankments in the mosses, but there is reason to believe he did so.

united to the heart of the soil by ties worked into it. The surface was then carefully covered with turf, and the water flowing over was led off from the foot of the slopes by conduits, ditches, or drains.

The thickness of this coating of sandy earth was 0^m 50 (1 foot eight inches) at top, for embankments 12 to 15 metres (40 feet to 50 feet) high. The argillaceous body of this embankment was sloped to an angle of 45 degrees, while the surface coating was formed in the proportion of one and a half of base to one of height, consequently, the layer of sandy earth increased in thickness from the summit towards the base. He used clay in thin layers, well puddled, alternately with the sand, from motives of economy; another advantage also resulted from this method, for the clay prevented the rain which fell on the surface of the embankment from filtering through the sand and effecting a separation between the two descriptions of soil forming the embankment.

These thin layers of clay were terminated at a short distance from the surface of the slopes, and their edges covered with sound earth, so that they were not exposed to contact with the air. The thickness of this covering has been wonderfully reduced on an embankment 16^m (52 feet 5 inches) high, executed at Chaville. The thickness of the covering at the foot of the slope was about 3^m to 4^m (9 feet 9 inches to 13 feet) wide, and carefully rammed; and the remainder, 0^m 50 to 1^m (20 inches to 39 inches) thick, which sufficed to protect the clay from contact with the air and the effects of frost, and thereby preserved them safe from accidents.

Clayey soils are not only subject to slip when employed in earthworks upon becoming diluted by rain or natural springs, but moreover, are very difficult to dry if they become wetted previous to being used. M. Delaserre obtained excellent results in the work just referred to, by mixing thin layers of sand with the beds of clay forming the body of the embankment, from 0^m 08 to 0^m 10 (3 inches to $3\frac{1}{2}$ inches) thick, to layers of clay 0^m 40 to 0^m 80 (16 inches to 32 inches) thick.

A portion of way 800^m (875 yards) long was executed entirely by embankments formed of clay properly dried. It was raised by wagons, and without any particular care excepting that the slopes were sprinkled with sand about (0^m 05) 2 inches thick, to facilitate vegetation and lessen the effect of rains. This embankment, which was between 4^m to 5^m (13 feet to 16 feet) high, has stood remarkably well. It is, however, prudent to employ clay in horizontal layers only, beaten and rammed, or rather executed with carts, and when the height of the

bank exceeds 5^m or 6^m (16 feet to 19 feet), it is essential to have recourse to the precautions we have described.*

All embankments are subject to settle, the materials of which they are composed becoming more closely united and denser in quantity after a short time, when the height of the work is consequently diminished. The amount of settlement varies chiefly with the nature of the materials of which the embankment is composed, its height, and the process adopted in forming the same. Certain kinds of soil settle much more than others, and earthworks formed with railway wagons, without being rammed, settle more than those which are subjected to this operation. Finally, the settling of an embankment varies, *ceteris paribus*, almost proportionately to the cube of its height.

The settling sometimes goes on for many years decreasing, until at length it ceases altogether.

We must not omit to estimate this shrinking in the formation of embankments as near as possible, and to make allowance for it. If earthworks did not settle, they would be formed of the proper height at first, according to the longitudinal elevation of the line, an allowance of about 0^m 50 (20 inches) being made for the thickness of the ballasting; but it is necessary to increase this height by the amount required for the settling. This excess has to be added to the height in practice, and varies from one end of an embankment to the other, in proportion to the cube of its height, above the level of the ground. Rails laid upon newly formed embankments present a series of rises and falls even in those portions where the slopes should be definitively uniform; but these rises and falls being in short lengths, are not detrimental to the working of the line, and their effects become diminished daily.

If, on the other hand, we were only to raise the embankment to the height shown on the section, not only would there be a constant expense in increasing successively the thickness of the ballasting forming the roadway, but also in the labour of raising the line as the soil settles.

It is proper for us to observe, that in calculating the excess of height necessary to give to an embankment as an allowance for settling, it would be better to err on the side of too little than to give it too much, for it is much easier, and consequently far less expensive, to heighten the road by adding ballasting than to lower it by digging under the sleepers.

The earth sometimes divides longitudinally at the time of settling; therefore,

* These details are taken from a memorandum of M. Delaserre, inserted in the Annals of Bridges and Highways.

upon the slightest indication of a crack being observed in this direction, the roadway should be taken up, and earth rammed into the aperture, so that the solidity of the embankment may not be injured by the introduction of water or gravel within it.

It is prudent to submit such embankments only on a line to the traffic which have already settled in part; and it would be advantageous to conduct the works in such a way as to accomplish this object, as far as possible, without retarding the opening of these lines of communication.

The natural desire of accommodating the public induced the managers of the Belgian Railways to open the line from Brussels to Mons when scarcely finished; the maintenance of the road has consequently been found very expensive. An arch of one of the viaducts in the section of Braisne le Comte à Manage recently gave way for a distance of about 25^{m} (82 feet), doubtless from the masonry being shaken by the passage of the trains before it had become sufficiently hardened; but no accident occurred to the passengers, thanks to the great care of the directors.

"The desire of entering into a participation of the benefits of a railway," says the Belgian Railway Journal, in discussing this point, "has cost enormous sums of money."

The greatest caution is required to be exercised in the construction of embankments in England, by the terms of the specifications for these works; also to prevent water penetrating them, either during the course of execution or after their completion. We will conclude this chapter on earthworks with the following extract from one of the specifications of the Railway from London to Birmingham:—

"The slope of all the embankments mentioned in this specification to have an inclination of two of base to one of height; the width of the embankment at the level of the red line is to be 33 feet after the earth and the turf have been placed thereon.

"Every embankment shall be constructed of the height and width stated in the specification, allowance being made for the settlement of the earth, and conformable to the instructions of the engineer. This clause will be strictly observed under every circumstance, in order to avoid the necessity afterwards of being obliged to add either to the height or width of the embankments, as the case may be, to bring them to the level required.

"The surfaces of the embankments are to be properly dressed and intersected by drains, in order to prevent the accumulation of water, and to secure their drainage during the period of formation.

"The contractor shall be bound to dress those slopes which are not laid to the proper inclination, as may be required; and this operation is to be performed as the work advances.

"When the earthworks have settled, the inclination shown by the diagram attached to this specification shall be given to their side slopes, and they shall be covered with a layer of turf, 8 inches thick, of which the grass shall be outermost. The turf is to be taken from the ground which the embankments are to occupy, and the earth must be taken from the surface, and afterwards spread over the sides in layers 6 inches deep. These side slopes are in this state to be sown with trefoil and lucerne mixed together in equal quantities. This sowing is to take place as soon as the season admits, in the proportion of 3 lb. of mixed seed per acre of slope.

"When any particles composing an embankment exceed 6 inches in diameter, they are to be broken in pieces."

CHAPTER III.

OF THE EXECUTION OF THE BED OF THE ROAD FOR THE RAILWAY, WITH A DESCRIPTION OF THE MATERIALS EMPLOYED IN ITS CONSTRUCTION, COMPRISING BLOCKS AND SLEEPERS.

Sect. I. — *Method of Construction.*

The bars of iron, or rails, forming the road of a railway, are fixed, as is well known, by means of cast iron sockets, which are called chairs, to bearers which constitute the foundation of the railway, consisting either of stone blocks or timber sleepers.

If these bearers were placed on the soil, without the intervention of any other substance, the road would settle unequally, and would become deranged, as the soil became washed away from the effect of rains, and to such a degree, that it would be impossible to travel at great velocity without the trains being constantly liable to be thrown off the line. These blocks or sleepers ought therefore to be placed on a pervious bed, so that the water which it occasionally receives may run off readily. This lower bed, and the layer covering it, in which the blocks or sleepers are buried, form together the ballasting, the thickness of which we have before stated is generally about 0^m 50 to 0^m 60 (20 to 24 inches). The railway is always inclosed by ditches on either side.

The mode of constructing the bed of the road depends on the nature of the soil on which it is to be laid.

It has to be formed—

First—In cuttings made in solid soil.

Secondly—On embankments raised on earth-work.

Thirdly—On soft moveable soil, either on the surface of the ground, or in cuttings.

In the cuttings a depth of 50 to 60 centimetres (20 to 24 inches) is cleared away below the level of the rails. As the earth is solid, the bottom is arranged so as to slope 3 centimetres (1 inch) from the centre towards each side. (See

Section of Earthwork, Plate I.) Then two small walls of dry stone are built on each side, parallel to the centre line, and which separate the road from the ditches. These walls have a batter of 1 in 10 next the ditches, and are equal in height to the roadway formed between them.

A layer of sand 0^m 25 (10 inches) thick, or of broken stones or small cinders, or any other substance which is pervious, is spread over the roadway. It must also be slightly elastic, since the roadway not only requires to be constantly dry, but also to possess some degree of elasticity, that the passage of the trains over the rails shall be as light as possible. The bearers are placed in rows along this bed, on which the rails are laid, and they are arranged either parallel or perpendicularly to the direction of the line. The stone blocks or sleepers of each pair of rails are laid more or less close, according to the weight of the rails; the blocks for each line of road are placed two by two perpendicularly to the centre; and their distance from centre to centre should equal the width of the way measured from centre to centre. The blocks, or the transverse sleepers, as the case may be, are first laid in the proper position, and the chairs are then fixed upon them. The rails are adjusted and secured in these chairs by means of wedges. The space between the blocks or the sleepers, and the level of the upper surface of the road, is filled in with the same material that is employed to form the bed of the road.

It is important that the blocks, but more especially that the sleepers, should be well covered with ballasting, which should be tightly rammed round them, to prevent, as much as possible, their getting displaced. This process also preserves the sleepers from rotting. It is especially necessary, in the curved parts of the line, that the ends of the sleepers situated on the outer curve should be well sustained by ballasting, for if this is neglected, the sleepers will frequently require to be pushed back into their proper positions.

We shall speak hereafter, in the fifth chapter, on "the laying down and maintenance of the way;" of the care which must be employed in adjusting and fixing each of these several parts accurately together, comprising the blocks or sleepers, chairs, rails, &c.

Stone blocks are less used in some parts than timber sleepers, as the latter possess a certain elasticity which is favourable to the preservation of the materials as well as to the motion. The stone blocks do not tie the two rails forming the way together, like the transverse sleepers, nor have the effect of maintaining the due distance between them. The use of sleepers likewise renders the settle-

ment more uniform, and they are less difficult to take up than stone blocks, when the road sinks, which reduces the cost of maintenance considerably.

Transverse sleepers should be exclusively used on embankments, and either blocks or sleepers may be employed in cuttings. Sleepers are, however, uniformly preferred at the present time, unless there is a great difference of price in favour of the blocks.

There is but one objection to be raised against the employment of sleepers, but it is a serious one, viz., the uncertainty respecting their durability, and the necessity which might arise, from time to time, of renewing them.

Various processes have been employed to preserve the sleepers. They have been soaked in corrosive sublimate in England, according to the patent process of Kyan, but the sublimate has been found too expensive in France, or its efficacy has been doubted. Crude creosote and different sulphates have been tried, and, lastly, a native of Bordeaux, M. Boucherie, has conceived the plan of impregnating the timber, while standing, with pyrolignite of iron, or even after it has been cut, but still in a green state, and with the foliage on. Hitherto none of these processes, save that of Kyan, has been employed on a scale sufficiently extensive, or for periods long enough to enable us to decide which is best.

We have made some experiments with the crude creosote, but the quantity of creosote absorbed was found so considerable that we were obliged to reject the use of this preservative, simply on account of its expense.

M. E. Prisse, formerly a pupil of the Central School of Arts and Manufactures, Engineer of Bridges and Highways in the Belgian service, has made some experiments in M. Boucherie's process; we extract the following notes from the information kindly afforded us by M. Prisse.

"The operation was tried principally on beech and poplar wood, the pyrolignite of iron was tried alone as a preservative, and mixed with a solution of common salt, and also with chloride of lime, and lastly chloride was used alone."

"The results were:—

"1st. That timber prepared in large masses was neither equally nor uniformly penetrated.

"2nd. That sleepers prepared, and even when well soaked, with the antiseptic, did not appear to remain sound as long as oak sleepers unprepared.

"3rd. They have not, in point of fact, yet observed any signs of alteration of the sleepers prepared and laid in the road, but it is different with other sleepers which have been buried in the earth.

" 4th. The sleepers which were buried in the month of March of last year (1842), commenced to show symptoms of decay at the end of November, while oak sleepers placed along with them at the same time remained perfectly sound.

" 5th. The rotting, or commencement of decay, observed in the poplar and beech sleepers, prepared with the various antiseptics already described, penetrated a depth equal to some millimetres (some small fractions of an inch), and exhibited a contraction of the fibres forming the wood, and the surface had become perfectly black and weak. The surface of the sleepers which were exposed to the air remained in good condition.

" 6th. The cost per sleeper for labour and expenses amounted to	0fr.	55c.	..	(5½*d.*)
For the Ingredients	0	20	..	(2*d.*)
For the Patentee's Licence	0	40	..	(4*d.*)
	1	15	..	(11½*d.*)

" 7th. According to the prices of wood in Belgium, the prime cost of a sleeper of white wood thus prepared would be nearly as much as one of pollard oak unprepared."

M. Prisse considered that it would be a great advantage to be able to substitute pollard oak for the same expense as white wood; but referring to the results before given, there is reason to fear that M. Boucherie's process is not so efficacious as was at first supposed.

The agent of M. Boucherie in Belgium states, that the estimate of expense given by M. Prisse is exaggerated, but this engineer still maintains its correctness, unless some more economical plan of preparation can be employed than that which he used.

M. Payen, Member of the Academy of Sciences, has also tested the process of M. Boucherie, and his results differ but little from those of M. Prisse.

The experiments of Messrs. Payen and Prisse, therefore, cast a doubt on the efficacy of M. Boucherie's process. We think, nevertheless, that it is necessary to repeat them before passing judgment on these means of preserving wood. The French government has ordered experiments to be made on a large scale, which will perhaps determine the question.

The various descriptions of wood are not all equally durable, and we shall state what kinds are to be preferred at a future period, in our remarks concerning the specifications for supplying railway sleepers.

Sand either loamy or only slightly so, and composed of large grains, is the material generally preferred for ballasting the road. We shall hereafter enlarge on the qualities it ought to possess to form a good roadway.

Broken stone roads are less homogeneous and less elastic than sand. We are not aware of many railways supported on sleepers laid on broken stone, but it has been in common use in the preparation of the beds for stone blocks.

Small coal has been often advantageously substituted for sand upon the English railways, as upon the Darlington and Stockton, Liverpool and Manchester Railways.

We are informed that broken bricks are employed on the line from Lille on the Belgian frontier. Bricks are also employed on the London and Croydon Railway.

We read in the last report of the Minister of Public Works to the Belgian Chambers, that a mixture of sand and forge cinders has been employed for the roadway of many lines in Belgium, the cinders being used on the surface.

Pebbles and scoria have been used at the bottom of the trenches, in some localities where the embankment consisted of peat, and in cuttings through wet earth, such as at the part between Boussu and the French frontier. Finally, Wishaw, in his work on English railways, states that a mixture of chalk and sand has been successfully employed, and also a mixture of sand and powdered freestone.

On a portion of the Stockton and Darlington Railway, Mr. Storey placed the blocks on small walls, but no English engineer, that we are aware of, has thought this method deserving of imitation.

On the line from St. Stephens to Lyons, solid masses of earth were left in the spaces between the rails, and also at the sides, to save ballasting. These masses were intersected by small cross drains in order to lead off the water to the side ditches, and the blocks placed in the longitudinal trenches, of which the bottoms and sides were covered with ballasting.

They diminished the quantity of ballasting in the Versailles Railway (left bank) by the same method, but soon found that it was impossible to keep up these masses of earth, on account of the action of the levers employed in repairing the road, the earth consequently became mixed with the sand, and deteriorated it in quality.

A small conduit is laid along the centre of the space between the rails on some English railways, communicating with conduits running transversely; the water, after passing over the ballasting, penetrates into these channels, and the dry stone

walls forming its sides, and the central conduits empty themselves by small gutters perpendicular to the road.

They have employed conduits of the same kind on the Belgian railways, but only at such parts of the road which are placed on a very moist soil.

Sometimes the dry stone walls supporting the road are dispensed with in the cuttings, and the ballasting takes its natural slope next the ditches, as the Versailles Railway, (right bank); the ballasting is very likely to be washed down by heavy rains into the ditches, when situated under these circumstances. It is also necessary in this case to enlarge the base of the cuttings, by the difference of width between the dry stone wall, and the slope of the ballasting.

The two sleepers situated on each side of a joint of the rails, are brought nearer together on some railways, as on the Orleans line: to diminish, as much as possible, the inequality of resistance which occurs at the joints, and to multiply the points of support of the rail, where it may be supposed to be weakest. It therefore becomes necessary to extend the distance between the other sleepers, or to increase their number.

When the road is laid on transverse sleepers, the inequalities in the resistance is less perceptible than when laid on blocks, but it is much the greatest at the passage over the joints.

They have attempted to remedy this inconvenience, not only by placing the adjacent sleepers nearer to the one receiving the joint, but they have laid the rails on a way consisting of longitudinal and transverse sleepers connected together, and also on longitudinal ones alone.

In adopting the first method of construction, that is to say, attaching the transverse sleepers to longitudinal beams, the former, being often subject to unequal settling, are rendered more compact, and the joints are supported against the pressure of the wheels.

It is requisite in this system, in order to attain the desired end, for the sleepers to be arranged in such a manner that their lower surfaces shall be exactly in the same plane, otherwise the ballasting supporting the frame ought to be very thick. The repairs, moreover, are attended with greater expense and more difficulty, than with the transverse sleepers alone.

This system of frame work is therefore only suitable in cases where the rails are fixed directly on the longitudinal timbers, without the intervention of chairs, since they then form a part of the rail, and the road itself, properly speaking, rests on a system of transverse sleepers.

When longitudinal beams are employed alone, they become buried in the bed

of the road, the soil being directly compressed, but if the iron rails, or rails formed of wood and iron, are supported by transverse sleepers, the effect of the pressure on the soil is diminished by the elasticity of these sleepers.

A portion of the sleepers on the Great Western Railway were supported originally by means of piles driven into the ground, the expense of which was considerable, but it was soon discovered that the rails bent between the points of support, although only a few yards apart, and to such a degree, that upon the expiration of a very short period of time the road presented a series of undulations, when the piles were consequently obliged to be removed.

Lastly, the rails were placed on a continuous wall of hewn stone, on a portion of a railway at Bolton, which was found very expensive, both in the construction and the maintenance, on account of its want of flexibility.

We will now return to the subject of the construction of the roadway.

The roadway is constructed on embankments, the same as in cuttings on solid soil, with this difference, that a greater width is given to the sides, and that the water generally runs over the surface of the slopes, instead of being conveyed away in drains; and it is not absolutely necessary to ram the surface on which the road is laid, as practised in cutting; the unequal settling of the embankment naturally producing compression. When the roadway is required to be laid on a soft earth, different expedients are employed, according to the nature of the soil; sometimes it is marshy, but easily drained, and of small depth; or it may be a very deep marsh; or, lastly, one of quicksand, of unknown depth.

If the soil can be easily drained, this is proceeded with, and when the earth becomes solid, it is completed by some of the methods already given.

If the marsh is of slight depth, and it is not thought easy or advisable to drain it, piles are driven into the solid earth below the marsh, and the tops of these piles are united by longitudinal timbers, on which cross sleepers are laid, and on these another course of longitudinal timbers are placed, which carry the rails.

This method was adopted for carrying the road over certain marshes in South Carolina, in the United States. This plan admits of the road being filled up solid, if necessary, and that portion of the marsh cleared out which it is required to pass over. If the marsh is of considerable depth, similar to Chat-moss, on the Liverpool and Manchester Railway, we must employ another plan.

In this case a layer of soil, equal to the ground plot of the road, should be drained to a depth of 15 to 18 inches, by means of parallel ditches, after the manner we have before pointed out. On this strip of land a bed of faggots must

be laid, and upon these a layer of pebbles, next a course of longitudinal and transverse timbers; and lastly, a second course of longitudinal sleepers, as shown in the Section through a swamp, Glasgow and Garnkirk Railway, Plate I.

The last case, or that of a quicksand of considerable depth, is met with on the Versailles Railway (left bank), at the bottom of a deep cutting, viz. that of the lime kilns.

They sank two tiers of planks about 1^{m} 0 (3 feet 3 inches) apart, along the side of each slope, in order to form the way, at certain distances, one on each side of the centre line. The earth inclosed between the courses of planks, was afterwards dug out, and walls of drystone constructed in the two excavations formed; with drains between them. A strip of land was thus drained between these two works, and the whole of the earth removed from it; and at the bottom of this large excavation a layer of large stones was carefully spread, on which a second was occasionally placed, and even a third layer of smaller stones; and, lastly, the ballasting was laid over the whole 0^{m} 50 (20 inches) thick, the same as upon solid land.

The part thus laid down has proved the best on the whole line. The road vibrates slightly when the trains pass over it, but it is not attended with any danger to the passengers.

SECT. II.—*Minutes of Specifications for supplying Sand, Broken Stone, Blocks, and Transverse Sleepers.*

The sand employed in the ballasting the road should be of middling quality, and sufficiently hard not to be either crushed or powdered by the passage of the trains.

Water does not run off so readily through fine sand, which moreover becomes injurious to the carriages, by lodging on the machinery, from being so easily drifted by the wind, or simply by the current of air produced by the passage of the trains. It penetrates the joints, and reaches even the boxes of the carriage axles, attaching itself to the grease used to lubricate them, thereby occasioning their destruction very speedily.

A mixture of sand, which contains a large proportion of clay, absorbs the water, and becomes converted into mud after heavy rains. It should therefore be rejected; but if the clay only bears a small proportion, so far from altering the quality of the sand, it gives a certain degree of consistency, and prevents its being too readily displaced.

The sand forming the bed of the road of the St. Germains and the Versailles Railways (right and left banks) is obtained from plains which modern geologists term *diluvial*, and is composed of fragments of every kind of rock. The grains of sand consist almost wholly of quartz, rounded by the action of water. The softer portions of the rocks from whence they proceeded have been carried by currents to a greater distance; a small quantity is thrown in and mixed with the former, which renders it slightly clayey, and consequently suitable in every respect for the purpose to which it is applied. River sand consists of *alluvial*, and is composed of grains nearly all of quartz, but it has no mixture of clay, like that of the plains; it is, however, used for some parts of the Versailles Railway, (left bank.)

We have also employed rather fine sand, with a sufficient quantity of clay in its composition, in which case it became necessary to assist the escape of the water by means of drains, or some other mode. Sand of the same character is also used in England and Belgium.

They have been obliged to suspend the working of the line of the Versailles Railway (right bank) for many months, in order to replace the sand, which was too clayey, with another kind, and of better quality, which was a great loss.

Good sand cannot be obtained in some localities, except at a very high price. The St. Germains Railway crosses sandy plains, and the sand did not cost more than 2 francs per cubic metre (35·317 cubic feet); it has amounted, upon certain parts of the Versailles Railway (left bank), and not at great distances from the pits, to 4 francs (3*s*. 4*d*.), 4 francs 50 cents (3*s*. 9*d*.), and 5 francs (4*s*. 2*d*.); and on other lines to 6 or 7 francs (5*s*. to 5*s*. 10*d*.) On the Lille line on the Belgian frontier it cost as much as 12 francs (10*s*.) Sand purchased at the pits seldom costs more than 50 to 75 cents (5*d*. to 7½*d*.) per cubic metre (35·371 cubic feet). It is the expense of carriage which increases its cost so much.

As 4 cubic metres (141·484 cubic feet) of sand are required per metre (3 feet 3 inches) in the construction of the road, and since a considerable quantity is used during the first year of the traffic, it is important to calculate this item of expense accurately in the estimates. A Company soon finds the advantage of undertaking the ballasting itself, being able to make use of its locomotives and wagons for that purpose.

A portion of the ballasting requisite for one of the lines on which the sleepers are intended to be laid, consisting of a bed of about 25 centimetres (10 inches) in thickness, ought to be laid by carts, but the remaining portion, and that which is intended for the bed of the second line, should be carried by wagons.

The sand is measured at the time it is deposited, by the contractor, upon the side of the road, although its volume is diminished when disposed along the roadway, by the compression which it undergoes in ramming.

Ballasting composed of broken stones should be, as near as possible, of equal hardness, and able, like sand, to resist any attempts to crush them. Such stones as are liable to be reduced to powder by frost should be rejected.

Any kind of stone may be used for the blocks, provided it is not too soft nor liable to be affected by frost.

They have used the refuse of coal workings on the St. Stephens and Lyons Railway, and masses of chalk and stone on that of Liverpool and Manchester, also granite on the Rouen line. The dimensions of these blocks should be fixed by the specifications. They are not less than 0^m 60 (24 inches) wide, 0^m 30 (12 inches) high on the English lines.

It is not essential they should be of a perfectly regular form, all that is requisite is a sufficient width of base to set well upon the bed of the road.

The sleepers ought to be wood of good quality, sufficiently dry, and as free from alburnum as possible. Oak is the wood that lasts longest, then red beech. White-leaved poplar, larch, and certain kinds of fir, perish very rapidly. Oak is exclusively employed on the railways in the environs of Paris, and on that of Strasbourg to Basle. Deal is employed for sleepers in England, but impregnated with the corrosive sublimate, oak being very scarce in that country. White wood of the worst quality having been laid down on the railway from Brussels to Antwerp, in Belgium, the sleepers required to be changed after six or seven years' wear, when Pollard oak was substituted instead. The wood employed for sleepers should be seasoned for one year at least. Wood which has laid some time in water, as that known at Paris by the name of *Bois-flotté* (floated wood), is the most esteemed. The wood for sleepers ought also to be sound and free from flaws, knots, or other defects, &c. The specification should give the limits maxima and minima for the size of sleepers: maxima, if they are paid for by the cube; minima, if by the piece.

It is of great importance that the sleepers should be of large size.

A line of rails laid upon sleepers which are too weak, wants solidity, and costs a great deal to maintain.

The sleepers placed under the joists, called joist-sleepers, should be re-selected from the best.

The sleepers ought to be long and large, to maintain their position in the earth. Their size should be comprised within certain limits, as it becomes impos-

sible to peck out the ballasting under sleepers of very large size. The sleepers being only sustained at the sides, while the pins that fasten the chains upon them are all four placed along their centres, it frequently happens that a sleeper splits through the middle as the trains are passing over it, when the chairs lose all their stability.

The dimensions specified for sleepers on the Versailles Railway (left bank) are—

	Metres.		Metres.		Ft.	In.		Ft.	In.
Length	2·20	to	2·40	..	(7	3	to	7	10)
Thickness . . .	0·15	to	0·20	..	(0	6	to	0	8)
Width	0·20	to	0·35	..	(0	8	to	1	1)

A fourth of the sleepers, at least, ought to be 0^m 30 (12 inches wide) for placing under the joints.

We have stated, that in using sleepers of less than 2^m 20 (7 feet 3 inches) in length, the greater part split when the pins are driven into them. The same accident occurs with sleepers of less than 0^m 15 (6 inches) thick, because the pins pass completely through them.

On the line from Strasbourg to Basle, the dimensions specified in the contract for sleepers were as follows, and a great number were delivered of larger dimensions:—

	M.	C.		Ft.	In.
Length	2	20	..	(7	3)
Width	0	25	..	(0	10)
Thickness	0	15	..	(0	6)

On most of the railways of the first class in England—as the Liverpool and Manchester, London and Southampton, Grand Junction, Nottingham and Derby, &c.—the length of the sleepers is usually 2^m 70 (8 feet 10 inches), and never less than 2^m 40 (7 feet 10 inches); their width is 0^m 22 (8 inches) to 0^m 25 (10 inches); the thickness, 0^m 11 to 0^m 14 (4 to 4½ inches); and the length of the pins is proportionate to the thickness.

On the Belgian Railways, recently constructed, the sleepers are also 2^m 70 (8 feet 10 inches) long. The sleepers on the Versailles Railway (left bank), and those of the Strasbourg to Basle line may therefore be considered as too short. It is proved by the effect produced on the ballasting by sleepers which have been taken up and removed, and which were from 2^m 20 to 2^m 40 (7 feet 3 inches to 7 feet 10 inches) long.

Upon the bed being examined, it was found to exhibit a slight alteration towards the centre of the sleeper, while at the extremities the finer sand had sunk down to the bottom of the roadway, and the coarser had risen to the surface; hence we must conclude that the movement of the sleepers was most considerable at their extremities, and, consequently, that the points which support the rails were too close to their extremities.

We have employed square sleepers in the environs of Paris, not that we believe square ones are preferable to the rounded, but because they are obtained in the trade more easily than others, when large timbers are required.

In Belgium and England almost all the railroads are laid upon round timbers sawn in half, and laid with their flat surface downwards.

A company should saw out the wood which it buys in the lump itself. It is, however, necessary that the chief engineer should exercise the greatest vigilance to prevent the mistakes which the carpenters whom he may employ in the sawing constantly make, and the numerous petty thefts which are so easily committed in a timber-yard.

This surveillance being very difficult, on account of the press of business connected with the management, a railway company will often find it advantageous to contract for the supplying of the sleepers. We have tried both methods on the Versailles Railway (left bank), and the result of our experience inclines us to prefer the latter.

When a company undertakes the sawing out of the sleepers, they should reserve the pieces arising from the operation for the manufacture of wedges.

The oak sleepers on the Versailles Railway (left bank) being a little more than 1 decistere (3·5317 cubic feet), cost the company about 7 francs 50 cent. (6*s.* 3*d.*) each. Sleepers of pollard oak only cost 3 francs 80 cent. (3*s.* 2½*d.*) on the line from Brussels to Antwerp.

The fir sleepers on the London and Birmingham Railway cost about 9 francs (7*s.* 6*d.*) each, and their preparation with corrosive sublimate added 90 cents (9*d.*) more to the expense. The cost of sleepers on other English lines has been a little under this price.

CHAPTER IV.

ON RAILS AND CHAIRS, AND MINUTES OF SPECIFICATIONS FOR THEIR MANUFACTURE.

Sect. I.—*On Rails and Chairs.*

Railways are divided into two classes: first, those formed of *Plate-rails*, and secondly, those of *Edge-rails*.

On railways of the first description, the iron bars constituting the plate-rails are formed of two pieces, placed at right angles to each other, comprising the horizontal part on which the wheels run, with a vertical projection, which prevents their running off the rails.

This vertical projection is always placed on the inside—that is to say, at the side nearest the axis of the line, by which the mud which tends to accumulate on the rails is thrown off upon the outside.

On lines constructed with edge-rails, the wheels of the carriages employed are furnished with flanges, which prevents their getting off the rails, as the latter have no projection whatever: the flanges are always placed on that side of the wheels nearest the centre of each line of rails.

The wagons or vehicles employed on a line laid with plate-rails would travel equally well on a common road, but it would be necessary to have a different carriage, in order to pass from a railway formed with edge-rails to an ordinary road. Notwithstanding this advantage possessed by lines formed with plate-rails over those with edge-rails, the latter are generally preferred, for this sole reason, that it is much easier to maintain the surface of the rails on which the wheels run more clean and even than the former. The use of plate-rails at the present time is almost universally abandoned, even in the working of mines and foundries, for which they had been long employed concurrently with edge-rails.

The rails used on the first railways established at the Newcastle coal mines, in about the year 1682, were of wood, and cast-iron rails were substituted towards the year 1738; but it was not until the year 1805 that rails of wrought-iron were employed.

Cast-iron rails are generally laid aside at the present time, and wrought-iron ones, or rails formed of wood and wrought-iron, are alone employed. The great objection to cast-iron rails is their liability to fracture; those of wrought iron are much less liable to break when the metal has been properly chosen and well forged.

Wrought-iron rails have another advantage over cast, which is an important one—viz., that of being able to be made in much longer lengths, since the greater part of the wrought-iron rails used in the present time are 4^m 50 (15 feet) long; some are even 4^m 80 (15 feet 8 inches), as upon the line from Paris to Rouen; while cast-iron rails were never made longer than 1^m 20 (3 feet 11 inches). The result is, that the joints on lines furnished with wrought-iron rails, and consequently the vibrations which take place at the joints, are much less frequent than on railways formed of cast-iron rails.

The price per ton of the cast-iron rails being generally less than the wrought, might lead us to suppose that railways constructed with cast-iron rails would be found less expensive than those laid down with wrought; but the contrary is the fact, for the cast-iron used in the manufacture of rails is required to be of the first quality, while that which is generally employed for the wrought is of the second.

Cast-iron rails cost almost as much as an equal weight of wrought-iron ones, and as an equal weight of wrought-iron rails offers a much greater resistance than those which are cast, they consequently make them of less dimensions, so that the wrought-iron rails cost less than the cast ones of equal length. Those lines which are laid down with wrought-iron rails have the advantage in an economic point of view over those formed of cast-iron.

Wrought iron being more subject to oxidation than cast, it was feared that the wrought-iron rails would be soon destroyed from the effects of rust, which does but little injury to cast-iron; nevertheless, experience has proved that the wrought-iron rails resist the influence of the atmosphere as well as the cast; the friction and pressure to which the rails are constantly exposed on the road produces a polish upon their surface, on which the wheels run, which probably contributes to preserve them from rust, whether they are cast or wrought. The lateral portions, no doubt, are protected by the crust of black oxide which always covers the surface of iron; the agitation and motion communicated to the rails by the passage of the trains may also contribute to preserve them from oxidation.

Experiments have proved that a magnetic current runs throughout the line. It has been affirmed also, that the action of this current is modified by the position

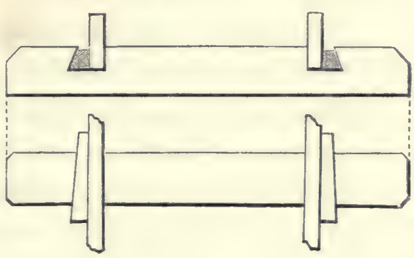
of the rails relative to the magnetic meridian, and by the direction taken by the traffic along the line; but we think this opinion has not been sufficiently well established, and even if it should be, it is no less certain that the action of the air would have no perceptible effect on wrought-iron rails on a line, when opened, whatever might be its direction and the number of the ways.

It has been asserted that wrought-iron rails are subject to exfoliate and to divide in the direction of their length, which does not happen to cast-iron rails; it is true, that we find the wrought-iron rails on many lines divided in the direction of their length, or reduced by a separation of the layers, which become detached from the upper surface; but this arises from defects in their manufacture, and may be avoided by observing proper precautions, which we shall point out on a future occasion.

Cast-iron rails resist the friction very well for a certain time, but they always consist of a hard crust, of little thickness, with softer metal within, and when the crust is once worn through, the rail is soon destroyed.

The form of edge-rails, both of cast and wrought, varies considerably. Rails of the following description are sometimes laid down on the temporary lines employed in the execution of earthworks, or for the carriage of materials, and for the railways used in mines, also in large foundries upon which light wagons only are used.

SECTION AND PLAN OF TEMPORARY RAILS.



This rail consists of a simple plate of bar-iron (*mi-plat*), which is laid directly upon the sleepers, and fixed in its position by means of wooden wedges, as shown in the cut.

This kind of rail is cheap, and after it is done with, may be disposed of as other iron for the purposes in trade, but it will not answer for a line on which the carriages travel at great speed and are heavily laden.

The friction on rails so narrow soon cuts and wears away the wheels. The lateral pressure which is exerted along the curves by the operation of the centrifugal force of the trains, bends the rails, unless the sleepers are placed at very short distances at these parts of the line.

Lastly, the rails bend between the points of support under the vertical pressure of the carriages, and rise up at their extremities, and so slip on to the wedge

and the side of the notch in the sleeper; and since they are not perfectly elastic, they finally become so much bent that jolts at the points of junction become very palpable.

The two first inconveniences which these *iron-bar* rails possess may be remedied by enlarging their upper faces on which the wheels run, and the last is in some degree corrected by adding projections at their lower parts, to catch in notches prepared for them in the cast-iron chairs, which should be securely fastened to the sleepers.

The rail laid on the line from Montpellier to Cette, a section of which is represented in Plate 2, belongs to this class, and details of a single chair of the Paris and Versailles Railway (left bank), Plate 5, show the mode of securing it.

The form which this rail assumes in section has caused it to be called the *champignon* (*mushroom*) headed rail. It consists of a head, or mushroom, properly speaking, a stem or centre rib supporting it, with projecting edges below, or bottom web.

The champignon-headed rail, with the top and bottom faces parallel throughout its length, was employed in the year 1828 on the line of St. Stephens to Lyons, and from St. Stephens to Roanne, in France.

The section resembled that of the rail employed on the line from Montpellier to Cette, but weighed 13 kilogrammes ($28\frac{1}{2}$ lbs.) per running metre—the chairs weighing 3 kilogrammes ($6\frac{1}{2}$ lbs.) with bearings of 0^{m} 90 (3 feet). As the projecting lower web was placed on one side of the girder only (see Plate 2), it becomes self-evident that it was requisite to fix the chair in a suitable position on the sleeper, since the rails were not able to be placed with the side web next the axis of the way without unfastening and changing the position of the chair. This defect has been remedied by forming webs on each side, as shown in the section of the rails of the Versailles Railway. (Plate 2.) Lastly, rails have been constructed symmetrically with double champignons, in order to allow of their being reversed. (See Plate 2.)

The single champignon-headed rail has acquired the name of the single or simple T rail, and the double-headed one has received that of the double T rail. The rails employed on nearly the whole of the great lines of railway consist of wrought iron T rails, either single or double, and more or less heavy. The shape of these rails, however, is not without inconvenience. The sides of the mushroom-shaped portions being unsupported, may be considered as in a very unfavourable position to resist the pressure of the wagons, and this circumstance is still more unfortunate, as we shall proceed to show that from the method of

manufacture, the champignon portion is generally composed of inferior iron, compared with the stem.

If we study the several processes in the manufacture of champignon rails, we see that the bundle of iron intended to form a rail is first passed under the drawing cylinders with pointed flutings,* and is drawn into a bar of nearly a square section, whose side width is less than the height of the rail, and something less than the width of the mushroom. It is necessary to perform the operation in this manner, or the laminage would perhaps require double the force that would otherwise be sufficient, whereby the cylinder would be broken, and the cost of the rails would be rendered too high. The iron is not always perfectly compressed when it passes through the grooves of the finishing cylinders, excepting at the thinner portions, and the rounded and salient portions are even sometimes expanded; thus when a champignon rail is accidentally broken, the stem may be seen to be much firmer and more homogeneous in grain than the mushroom portion, while we can trace unsound and badly-wrought portions in the latter. It therefore follows, that the difficulty of manufacture increases with the weight of the rail, and that the interior portion of a large bar is more defective than that of one of less size, and these imperfections are still more considerable in a champignon rail badly compressed than in an ordinary iron bar.

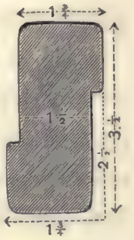
Two engineers of great experience, Messrs. Wood and Storey, proposed to remedy this defect by forming the mushroom of a small portion of hammered iron. The plan consisted in re-covering the bundle to be laminated with a small portion of hammered iron, of nearly one-third the weight of the bar, and to direct the working in such a manner as to form the mushroom of this portion, so that the interior should be formed perfectly homogeneous.

This process, however, possessed difficulties, since iron of different qualities requires to be heated at different temperatures; that which is to be hammered out generally requires greater heat than that which is to be drawn out; therefore, when the temperature would be sufficient for one portion of the bundle, the other would be either burnt up or otherwise too cool, so that the mushroom-head would not be welded in a perfect manner to the stem of the rail.

We have seen rails manufactured after this plan at a foundry in the neigh-

* For an account of the processes in the manufacture of iron, see the *Métallurgie du fer*, by M. Walter, Professor at the Central Schools of Arts and Manufactures. The work on the same subject, by MM. Eugene Flachat, civil engineer, Jules Petiet, and Barrault, formerly pupils of the Central School, and *Voyage Métallurgique en Angleterre* (second edition), by MM. Dufrenoy, Etude Beaumont, Coste et Perdonnet.

bourhood of Newcastle, but they have not been extensively used, most likely on account of the rails dividing into two pieces. M. Leon Coste has endeavoured to obviate the defects that we have just pointed out in the champignon rail, by altering the form of the rail to nearly that of a simple plate bar, with the angular edges rounded off, and he has replaced a part of the line from St. Stephen to Lyons, originally laid with champignon rails, with rails of this description.



The rail is sufficiently wide not to wear away the wheels of the locomotives or carriages, and it is provided with flanges, which enables it to resist the lateral pressure upon the curves, and by means of which its extremities are maintained in the chair like the champignon-headed rail, and its form admits of being turned upside down, if required. This rail, however, is deficient in height, which is a great defect; and since its flexibility as well as its resistance to fracture varies with the square of the height, it is found too elastic.

If it was formed of greater height, and its width at the same time preserved, it would have been necessary to have increased the weight beyond the limits to which it is necessary to be restricted. Therefore, one of the defects of the champignon is merely remedied by substituting a rail of equal thickness, and which is equally objectionable in another respect, since experience has proved that these rails are destroyed as quickly as the former ones; that they do not unite so firmly to the cast-iron chairs as the champignon rails; and lastly, that they do not sufficiently secure the chairs from contact with the carriage-wheels.

We have adopted a rail on the Versailles line (left bank), which may be considered to resemble both that of M. Coste and the old champignon-headed rail.

Allowing the same quantity of metal to form our rail that is used for the greater part of the double T rails on the French railways, including the rails laid down by M. Coste, or 30 kilogrammes to the metre (61 lbs. per yard), we have endeavoured to distribute it in such a manner as to obtain a rail which, without presenting the inconveniences of M. Coste's rail, should possess some of its advantages. This rail, which is represented in Plate 2, is a simple champignon-headed rail. It affords nearly the same height and width for the passage of the wheels as the double champignon rail of the weight of 30 kilogrammes to the metre (61 lbs. per yard); but part of the metal, instead of being used to form the second champignon, has been placed beneath the single champignon head in such a way as to support its sides and to increase the thickness of the stem. The champignon being thus strengthened, offers a greater resistance to any force exerted upon it; and although the bar, in passing under the rolling cylinder, is

not so equally compressed throughout as M. Coste's rail, the injurious effects of this inequality of compression are at least reduced, as the difference between the thickness of the champignon and that of the stem is so much less, compared with the double champignon.

Our single T rail cannot be inverted like the double T rail; but when we find that the single-headed champignon rail, of the shape and dimensions such as we have given it, is likely to last longer than the ordinary rail with double champignons, the advantage will be in its favour.

If, upon one of the champignons of the double T rail becoming, in the course of time, worn out by the passage of the trains, and on our turning and replacing it by the lower one, we were to expect that the latter would be in the same condition as the first when the rail was new, we should be deceived. Professor Barlow, so well known for his experiments on the strength of iron, and the author of a valuable work on the form of Rails,* has with reason observed, that if the lower parts of the rails in use upon a railway are not worn by the friction, they are not less so by the action of the weight of the trains; so that, in fact, when a bar, resting on supports, bends with the effect of a transverse strain, the fibres at the side of the convex face are elongated, and those at the side of the concave face are shortened, while certain fibres in the interior of the body of the bar preserve the same length. The line which separates the contracted from the extended fibres is called the *neutral axis.* Professor Barlow observes, that the neutral axis in these bars of iron is placed between the third and fifth portions of their height, reckoned from the line of their upper surface, since the shortening or lengthening of the lower fibres of the bar is in proportion to their distance from the neutral axis; the extension of the lower fibres is therefore greater than the contraction of the upper ones.

This being, continues Professor Barlow, an established fact, I consider those engineers very short sighted who make the upper and lower mushrooms in double T rails of the same figure, for, in the event of the upper mushroom being worn out, and it is proposed to turn the rail for the purpose of replacing the upper part with the lower; then, since the lower table supports the greater strain, to turn a rail which has been subjected for many years to a great compressing force, (therefore, as may be supposed, greatly altered,) and expect it to sustain still greater strains of extension, will be, continues Professor Barlow,

* *Expériences sur la force transversale et les autres propriétés du fer malléable, dans son application aux chemins de fer,* par P. Barlow. Traduit de l'Anglais par C. Quilhet, ancien élève de l'Ecole Polytechnique.

a dangerous experiment. It is for this reason he recommends that all rails should, on the contrary, be furnished with metal at their lower parts, or base, and of the most suitable form for present purposes, without regard to the future.

It is also stated of the double T rail, says the same author, that as the two sides are alike, whichever adjusts itself best can be placed upwards when it is laid down, but it would certainly be preferable to have the rails manufactured sufficiently uniform that no choice remained to be made.

We need merely observe, in conclusion, that supposing it desirable to invert the double T rail upon the upper mushroom getting out of shape from the effects of pressure and friction, it would not, in general, fit the sides of the chair with sufficient exactness: the stability of the road would therefore be very imperfect, and the fracture of the chairs more frequent.

We consider the single T rail of the model that we have described to be more durable than the double T, containing the same weight of metal per metre, and this is not the only advantage which it possesses over the same.

It is necessary to provide facilities for introducing the rail from above into the socket of the chair in the employment of the double T rail, either vertically or inclined on one side. The space prepared for the reception of the rail in the chair, being of great width, renders it necessary to have the wooden wedges very thick, in order to fix the rail; the chairs are also required to be very long, which renders them too heavy; the wedges also soon slip out. The single T rail, on the contrary, can be fixed with a small chair and a smaller sized wedge, which reduces the cost of the chairs, while it increases their stability.

In short, although our single T rails cannot be turned or rendered serviceable for lines of the first class; they will at least serve for earthwork, or for the execution of smaller undertakings.

The double T rails are said to possess an advantage over the single ones, in being less likely to upset, since they rest in the chairs upon a larger base. We have not, however, heard of any engineer complaining that the lines laid down with single T rails were deficient in stability. The single T rail does not, according to the general opinion, resist either the vertical or the lateral pressure so well as the double T rail of equal weight, and it is not quite so stiff as the latter, which is a defect. But the difference of resistance, whether to rupture or flexion, is so small that, practically, it has no injurious effect.

Although we employ the heaviest engines on the Versailles line (left bank), we have never found that our rails were either deficient in strength or too flexible.

Professor Barlow asserts, that the shape of the double T rail does not correspond with the form which theory would assign to produce the *maximum* of resistance.

The following Table of Experiments made at the Decazeville Foundry for the purpose of comparing the strength of double and single T rails, will, however, lead to a contrary conclusion.*

The numbers referring to the rails used on the Orleans line, and given in this Table, are the mean results of experiments made upon the rails whose casings or coverings were made (the first) with a mixture of fine metal and scrap iron, the second with pure fine metal, the third with a mixture of fine metal and cast with wood, which was used instead of the scrap iron.†

In making the above experiments, the rails were placed on supports 0^m 05 (2 inches) wide and 1^m 25 (4 feet 1 inch) apart, from centre to centre.

TABLE OF THE STRENGTH OF RAILS.‡

Weight in Tons.	DEFLECTIONS CORRESPONDING TO THE WEIGHT.					
	Rail from Paris to Orleans, No. 1.	Rail from Paris to Orleans, No. 2.	Rail from Paris to Orleans, No. 3.	Rail of St. Germain.	Rail of Versailles (Left Bank). The Larger Champignon.	The Smaller Champignon.
	Met.	Met.	Met.	Met.	Met.	Met.
8·00	0·00000	0·00150	0·00075	0·000000	0·00250	0·000000
9·00	0·00000	0·00250	0·00125	0·000000	0·00325	0·003500
10·00	0·00050	0·00300	0·00175	0·000750	0·00400	0·004500
11·00	0·00100	0·00375	0·00275	0·001000	0·00600	0·005000
12·00	0·00125	0·00450	0·00300	0·002000	0·00700	0·005500
13·00	0·00150	0·00555	0·00350	0·003500	0·00850	0·006500
14·00	0.00250	0·00650	0·00450	0·004000	0·00900	0·008000
15·00	0·00500	0·01100	0·00700	0·005000	0·01300	0·010500
16·00	0·01200	0·02100	0·00825	0·006500	0·02300	0·013000
17·00	0·01350	0·03150	0·01400	0·009000	0·03350	0·020000
18·00	0·02500	0·04100	broke	0·018000	broke	0·28000
19·00	0·03750	broke	do.	0.025000	do.	0·38000
20·00	0·04750	do.	do.	0·031000	do.	broke
21·00	0·05650	do.	do.	0·048500	do.	do.
22·00	0·07550	do.	do.	0·065000	do.	do.
22·50	broke	do.	do.	do.	do.	do.
23·00	do.	do.	do	0·080000	do.	do.
24·00	do.	do.	do.	broke	do.	do.

* This table is extracted from the work of MM. Eugene Flachat, Jules Petiet, and Barrault, already cited.

† These experiments were communicated to us by M. L. de Barruel, the officer appointed to receive the rails on the Versailles Railway (left bank), and afterwards for that of Orleans.

‡ See further observations in the article on the manufacture of railway bars. See, also, the plates of rails and explanations.

The weight was applied merely momentarily, and confined to a space of 0^{m} 07 ($2\frac{6}{7}$ inches) in the middle, and the apparatus was not disposed in such a manner as to allow sufficient time to prove that the rail underwent the whole extent of deflection that the load was capable of producing upon it. These experiments, however, sufficed as a means of comparison. None of the several rails experimented upon exhibited any sensible signs of deflection under a weight of eight tons.

Time only can determine the question respecting the relative durability of single and double T rails, containing the same weight of metal. It is therefore highly desirable that those engineers who have the direction of these channels of communication should collect all documents which might lead to the solution of the problem, together with the numerous others connected with the subject of railways.

The Minister of Public Works at Belgium, in which country this new system of communication has been much developed, did us the honour of communicating an idea which occurred to him of calling a meeting of the engineers and directors of railways established there, and we regret that his design has not yet been carried out, but trust it will not be abandoned.

It remains for companies so enlightened and liberal as those of the Belgian railways to set the example.

Returning to our examination of the qualities and defects of the single and double T rails, we beg to state that opinions on this point are at present so divided, that the railways recently constructed with the two descriptions of rails are about equal in number and importance.

The single T rails are adopted in nearly all the railways in the North of England on the North Midland Railway, on the line of the Manchester and Leeds, the Eastern Counties and the Greenwich, the whole of the Belgian Railways, the line from Berlin to Potsdam, the Versailles Railway, (left bank,) those of Montpelier to Cette, of Bordeaux to the Teste, and on that from Naples to Nocerra.

The double T rail on the other side has obtained the preference on the railway from Liverpool to Manchester, the London and Birmingham, the Grand Junction, the London and Southampton, the Paris to St. Germains, to Versailles, (right bank), to Orleans, and to Rouen, the St. Stephens and Lyons. Strasbourg and Basle, and the St. Petersburgh to Paulosk.

It may be seen upon an inspection of Plates 1, 2, 3, 4, and 5, that engineers have not restricted themselves to varying the relative dimensions of the champignon and of the stem only, but have also modified their shape.

Thus we see the rails on the line of the St. Germains, and on the Liverpool and Manchester, (see Plate 2,) have the champignon rounded on one of the sides, and finished by an acute angle on the other, which has the effect of extending the surface on which the wheels run in a small degree. The convex face of the champignon is obliged to be placed next the centre of the way, and experience has proved that the sharp edge, from being frequently defective, is soon destroyed. The double champignon rail, but without these acute edges, was also employed on the Versailles line, (right bank,) which was constructed by the same engineers as the St. Germains Railway, after the completion of the latter.

The surface of the champignon on which the wheels run was originally convex, as the original rail on the line from Newcastle to Carlisle, which has been since replaced by one with a plane surface, but there has been a return during the last few years to the convex shaped rails. The new rails of the railway from Orleans to Rouen, and of St. Stephens to Lyons are formed convex on their upper surface.

The flat surface occasions great disadvantages. The wheels of the carriages being formed conical in order to facilitate their passage along the curves; rails formed with flat surfaces are consequently inclined in a direction towards the centre of the road, so that the conical face shall run along the centre part of the champignon: an excess of friction is therefore the result on the straight parts of the line, and slipping in proportion as the surface of the rail is enlarged, since a cone cannot move in a right line along a plane without slipping. Again, if the inclination of the surface of the rail is not exactly the same as that of the periphery of the wheel, which is seldom the case, the conical wheels rest only on the interior or exterior edges of the champignons, in passing along them, which cause them to scale. And wherever the inclination of the rails forming the same line of way, differs, it occasions (together with the parts preceding and following this imperfection,) lateral oscillations, which increase the movements of the apparatus.*

* When the two conical wheels of a railway carriage are required to move in a right line along the road, it is necessary that they should rest on the rails at points of equal distance from the flanges of the wheels. If, in consequence of any lateral influence whatever, the flanges of one of the wheels should approach nearer the rail, and the other get further removed from it, the carriage no longer moves in a right line; the wheels turn along the road in such a manner that the flange which was furthest from the rail approaches nearer, and that which was the nearest becomes more distant.

It is true that the two flanges are situated at equal distances again from the rails during this process, but for a single instant only, in consequence of the velocity they have acquired obliging them to pass over it; the flange which at first was the most distant becomes nearest, and *vice versâ.* The movement of the carriages is therefore in contrary directions, and their course is rendered tortuous instead of direct and straight.

The inconveniences which we have just described are avoided by making the rails convex, but there is reason to fear that the action of the wheels being confined to such a small extent upon the rails, would rapidly wear away their surface, and that the champignon would be worn down in the course of a short space of time. It is not unlikely that it was a knowledge of this fact that led to the abandonment of convex rails.

The rails adopted at the present time on all the great railways are, with few exceptions, made of the same height throughout their entire length, being called *parallel rails*, so that a transverse section always presents the same profile wherever it may be taken. There is another description of rail which has been in use for some years past, whose vertical section varies between the points of support in such a way as to afford a corresponding degree of resistance throughout to the weight of the load. These rails, which are called *undulating* (*ondules*), or *fish-bellied rails*, on account of their lower edge being formed in an undulating line, are abandoned at the present time, and for the following reasons:

1st. The sleepers, which ought always to be perpendicular to the centre of the road, cannot be so disposed along the curves, inasmuch as the distances between the points of support are greater on the line of rail forming the outside curve than on that constituting the inner one, the difference of distance between the points of support ought to vary with the radii of the curves, but when fish-bellied rails are used, these distances are necessarily made equal.

2nd. The points of support of fish-bellied rails being necessarily always placed at equal distances, it therefore follows that when a rail becomes broken or gets bent between the supports, it is not possible to slip a sleeper underneath to sustain it, which is often done with the straight or parallel rails, as they are called.

3rd. It is equally impossible to vary the number of the points of support with fish-bellied rails according to the nature of the soil, weight of the engines, or any other circumstance which may require them to be altered.

4th. If the soil beneath the supports of a fish-bellied rail, or even a single support, happens to sink, the rail is immediately suspended, as it were, above the soil, and consequently weakened at the very point where it is required to resist the greatest strain.

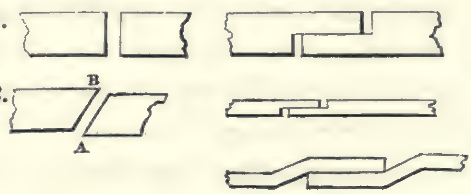
5th. The fish-bellied rail contains less metal, according to theory, for an equality of resistance than the parallel rail, but the metal forming it being unequally compressed, is less homogeneous. The manufacture of fish-bellied rails, moreover, presents greater difficulties than parallel rails. Unless formed with the requisite accuracy, they lose their proper solidity.

6th. Lastly, fish-bellied rails are more difficult to manufacture than parallel rails, and cost as much as the latter, although they contain less metal, and when fish-bellied rails are worn out, they are found to have lost the greatest part of their value.

The old cast-iron rails all take the form of a section of equal resistance, but since they never exceed a length of 1^{m} 20 (3 feet 11 inches), they rest on supports at either extremity, the line forming the lower edge is consequently of a convex form throughout.

The rails are sometimes simply laid end to end, forming a straight joint, either of a square or a diagonal shape, as shown by the following cuts. See Figs. 1 and 2.

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.



Sometimes the champignons are halved in the middle and lapped together, as shown in Fig. 3, the stems being joined in a similar manner, as shown at Fig. 4, or after the plan of Fig. 5. The mode of uniting the rails exhibited in Fig. 1, is exclusively employed on all the French railways, and on a great number of English lines.

The method shown at Fig. 2, has been employed in Belgium. The jolts at the passing of the carriages over joints formed in this manner are not so perceptible as those of Fig. 1, but when the lateral surfaces of the rails are not laid in a straight line, as they should be, but are as shown in Fig. 2, and the flange of the wheels happens to strike or even press laterally against the acute angle A, or against the angle B, the rail is soon broken.

The method shown in Fig. 3, although expensive, has obtained the preference for some years past on many important lines, especially in Belgium, the stems being finished as shown in Fig. 5.*

The whole of the rails that we have at present described are always fixed either on stone blocks or wooden sleepers, by means of cast-iron chairs, but champignon rails terminated below by flat feet, which rest immediately on the sleepers, have also been employed. (See the lower row of rails among the specimens exhibited on Plate 3.) These rails are known by the name of *American Rails*, and are kept in their position by iron spikes, as shown in the section of the "Rail tried on the St. Germains Railway," Plate 5.

* See Plate I. "First Series of Railway Practice." Third Edition.—*Tr.*

The American rails have been tried on the St. Germains line, where the method of uniting them to the sleepers was found to be deficient in stability, more particularly upon the curves. The lateral pressure of the trains, it is believed, produces this effect upon the fastenings, by forcing the rail from the inside of the way towards the outside. A similar effect is produced upon the pins which are employed to attach the chairs to the blocks and to the sleepers, with rails of the ordinary description, but in a much less degree. This no doubt arises principally from the imperfect union between the rail and the chair. The rail possesses but a weak hold in the latter, more especially when wooden wedges are employed.

M. Minard, in the course of his lectures upon railways, delivered at the School for Bridges and Highways, expressed himself as follows: " The rails were originally terminated at each extremity by contrivances resembling ears, which were applied upon the blocks and fastened thereto by nails, the rails being placed together end to end by this method. The weight was entirely borne on the four extremities of the ears, and when the upper surfaces of the three contiguous blocks got out of the same plane, the ears which received the direct action of the wagons became twisted, and were often subjected to fracture; the rigidity of the cast-iron, further, did not allow of the whole yielding together."

" Hence the idea arose of interposing a third body between the rail and the block, in order to weaken the shocks as much as possible, and the rails were secured to the blocks by the help of an intermediate and separate piece of cast-iron, called a *chair*. These chairs were fixed to the blocks by two pins."

M. Minard refers to cast-iron rails, but his remarks apply equally to wrought iron, with this difference only, that the ears do not break in the latter case, but the pins or bolts connected with the fastenings come out.

Rails formed of wood and iron (*longitudinal bearings*) are often employed in the United States, but are much less general in Europe. They have, however, already been employed on several railways in Germany and in England. The following English lines are laid upon longitudinal bearings, with rails constructed of wood and iron: the Great Western, the London and Croydon, the Ulster, the Newcastle and North Shields. Rails formed of wood and iron are employed on different portions of some other lines where wrought-iron rails, after the usual plan, are adopted. Rails laid on longitudinal bearings are used in Germany upon the railway from Heidelberg to Manheim, the Carlsruhe and Magdeburg, the Leipsic and Dresden.

Rails consisting of a longitudinal sleeper with a bar of flat iron screwed down on the sleepers have been used in the United States, but the screws have been soon

found to get loose. Rails of this description are not to be found on any line of importance in Europe.

The portion formed of iron in the rails constructed of wood and iron is always either a champignon head, formed with a base, as the rails of the Newcastle and North Shields and other railways, (see Plate 3,) or a rail sloped like those of the Great Western and other railways, and known as *bridge rails.* (See Plate 3.) Each of these descriptions of rails are fixed to the longitudinal sleepers, either by spikes, like those used with the rail tried upon the St. Germains Railway, (Plate 5,) by screws, or by bolts, as the champignon rails with feet, are secured.

The longitudinal beams which we consider as forming a constituent part of the rail in lines formed upon the system of continuous bearings, are fastened to the transverse sleepers by bolts or trenails. Whatever form may be given to the iron rails fixed upon the longitudinal sleepers, they ought always to be fastened with cast iron feet plates let into the timber. They require to be cut at the ends, either obliquely or square, to form the joints.

The ratio between the height and the base of the iron portion of the rail being much less with rails formed with wood and iron than with the champignon-headed rails laid on chairs; and as they may be secured with as many fastenings as desired, they are therefore less likely to get twisted. They also possess a much greater degree of elasticity than ordinary iron rails, which tends to preserve the materials, and eases the motion of the carriages.

In localities where timber is dear they are more expensive than rails formed entirely of iron, notwithstanding the price of iron may be low. They appear, however, to be less durable, and occasion an inconvenience in being more difficult to raise and replace than iron rails fixed by means of wooden wedges between the cheeks of the chairs, which defect may become serious when the traffic is considerable.

Of the two descriptions of iron rails which are fixed upon longitudinal sleepers constituting the lines of way—namely, the champignon rail, formed with feet, and the bridge rail, the latter appears to us to be preferable, as the metal is the most equally compressed. This rail is consequently more homogeneous, and the surface upon which the rails run is not so subject to wear down as the champignon.

We shall now conclude our description of the different kinds of rails, in which we have alluded more particularly to their shape, and pass on to compare the different modes employed of attaching them to the ground.

In our statements of the respective advantages of the ordinary champignon

or T rails and the American rails, we give the preference to the mode of fastening adopted with the first over that employed for the latter.

We will now enter into some details which occur in the practice of each of these methods.

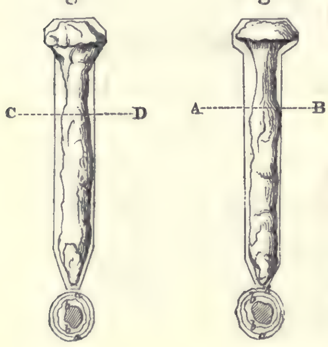
The chairs are fixed to the sleepers, or to the blocks, by trenails and iron pins, which are passed through their feet-plates. When stone-blocks are employed, they are drilled with holes for the chairs at the spot, to receive the trenails, into which the iron pins are driven.

M. Manby has communicated to the Railway Journal an excellent article on the respective advantages of iron and wooden bolts for fixing the chairs to their supports, from which we extract the following passage:—

" Stone blocks were employed to support the chairs upon the first railways constructed for the conveyance of passengers; but in the present practice of the profession it is generally admitted that wooden sleepers are far preferable, as they maintain the width of the way more correctly; since, by extending the same base to both sides of the way, the two parallel lines of rail forming each line thereby assist each other. In all the various methods adopted of forming the supports, iron pins are, with few exceptions, always employed to fix the chairs to the sleepers, and which we shall soon refer to."

" The great experience already possessed by our English neighbours on all points relative to the construction of railways, led them to a discovery of the defects of iron fastenings; and the want of an efficient substitute alone induced them to continue their use, without alteration, up to a late period, until the recent experiments of Mr. William Cubitt appear to have afforded the desideratum required."

Fig. 1. Fig. 2.



" In order to give some idea of the alteration which takes place with iron fastenings, and the various effects that result from the same, we have annexed a representation of some iron bolts, which were taken up on the Liverpool and Manchester Railway, after being down many years, which are carefully drawn at a fourth of their real size."

" We observe, on examining these cuts, that the bolts are not formed exactly of the shape required to fill the holes drilled in the chairs to receive them; in consequence of which defect in their original manufacture, and which cannot be avoided where economy has to be considered, there is a want of connexion between

them which has allowed the water to get into the hole in the chair along with the bolt, by which the oxidation of both is very quickly effected. If to this destructive agency we add the shaking which takes place between these two bodies in contact, but not united together, by the passing of the trains, it may be easily conceived that every vibration causes a shock of the bolt against the chair which detaches the several layers of rust as fast as they accumulate."

"Fig. 2 represents the section of a bolt which was originally 19 millimetres (.748 inches) in diameter, but was reduced by the above-mentioned causes to 9 millimetres (.354 inches) only, while the corresponding hole in the chair was increased in the same way from 19 to 23 millimetres, (.9 inches,) so that a space of 14 millimetres (.55 inches) remained in the chair for the bolt to play. This figure shows that iron fastenings, which are preferred, *à priori*, as possessing the greatest strength, and as the most secure, are far from answering the expectations formed of them in practice."

"The defects which arise from the careless manner in which the chairs are usually made, are as serious as those we have just described in reference to the bolts. There is a want of uniformity, the natural result of their being moulded by the hands of different workmen of unequal ability, which produces a want of stability in the chair in its connexion with the sleeper, and the rail with the chair, as well as a want of parallelism between corresponding rails, and a deficiency in the uniformity of the necessary inclination of the rails towards the centre of the line. It is impossible to form even an approximate calculation of the loss occasioned by these general imperfections, both in the system of fastening, and in the casting of the chairs. The expense of renewing the bolts is nothing compared to the destruction in other parts of the construction. In the first place, the sleepers get displaced by the jolts, and not being able to receive the bolts again in the same holes, are obliged to be changed. Secondly, the chairs get twisted and broken. The engines and wagons are, however, more particularly affected, in consequence of the want of stability of the road, they are jolted along, by which they sometimes get off the line. The damage direct and indirect is incalculable, especially when from any of the above enumerated causes, one of those unfortunate accidents, by which the safety of the passengers is endangered, and which are so much to be lamented, occurs; hence demands arise, together with verdicts of indemnity, the payment of which always falls upon the companies."

"It was for the purpose of remedying these great and numerous defects that Mr. William Cubitt, whom we have already mentioned, instructed Messrs. Ransome and May, skilful engineers at Ipswich, to try some experiments, from which

certain improvements have resulted, which we are about to describe, and with which, through the kindness of Messrs. Manby, brothers, we are well acquainted."

"The chair represented in Figs. 1, 2, and 3, is that employed on the South Eastern Railway, and of a new pattern. The points of resistance, and the edges are placed in such a manner as to give the chair all the solidity and strength requisite without unnecessarily increasing its weight. A rim, c, Fig. 2, which partly covers the wedge B, has been so disposed, as to fix the rail immoveable in the chair. As it is of the highest importance to prevent all rising of the rail, the rim, c, of the intermediate point is prolonged in the joint chairs, as shown by the dotted lines, Fig. 2. The holes, *b*, Fig. 3, formed in the feet of the chair to receive the bolts, have been arranged in a new way; instead of being in the same line as in ordinary chairs, their centres take two different vertical planes. The object of this change is to prevent the sleepers being split, either in driving the bolts, or by the passage of the trains, since they are much weakened by the two holes being in the same line, and passing through the same fibres of the wood. The greatest improvement in the manufacture of these chairs consists in the employment of a centre and a metal mould, which secures an exact shape and a uniform casting, free from roughness. The employment of a metal mould is more valuable than all, because it secures the seating of the rail with mathematical precision in the place it is intended to fill in the chair, as well as the requisite inclination toward the centre of the way; without the workmen who fasten the wedges having the power, either from negligence or clumsiness, of fixing the rail in a wrong position."

Fig. 1.

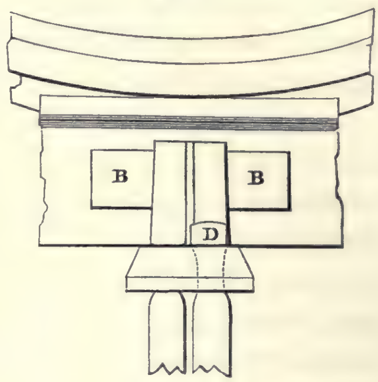


Fig. 2.

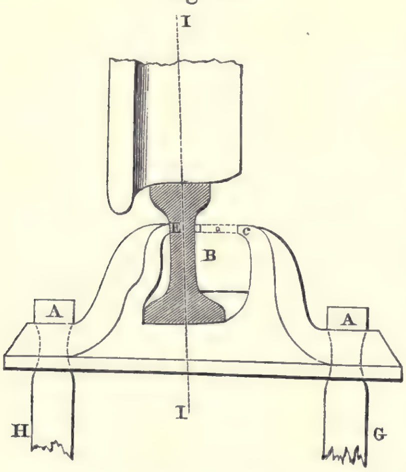
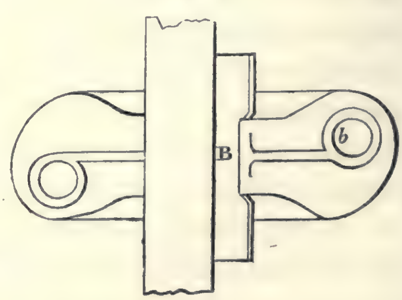


Fig. 3.



"The mathematical exactness of all the several parts of the chairs is

considered so very important by Mr. William Cubitt, that he caused all the chairs intended for the South Eastern Railway, (of which he was the engineer in chief,) to be examined one by one, and every chair in which the points of contact of the rail with the checks varied only the fraction of an inch in its relation to the base, was by his orders rejected. We must, however, add in reference to this point, that among all the chairs cast by Messrs. Ransome and May, of this shape, there were not 2 per cent. returned to the foundry in twelve months as faulty, and that among 4,000,000 kilogrammes, (8,820,000 lbs.) of cast iron chairs delivered for the South Eastern Railway, not one was refused, notwithstanding the strict examination to which they were subjected. This remarkable fact proves at once the great care bestowed by the founders upon the work, and the superiority obtained by machinery over that of the hand."

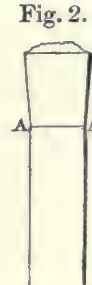
" We stated at the commencement that the great defects occasioned by the use of iron fastenings, led engineers to try many expedients, and the substitution of wooden pins for the iron ones, for fixing the chairs to the sleepers was tried, but without obtaining much success. Wooden bolts, used in their natural state, do not answer in dry seasons, as they shrink, and lose some portion of their bulk, which make the chairs ricketty, and occasion alterations in the work, which always end in considerable expense to the Company in the maintenance. Notwithstanding the imperfections of trenails, the defects of iron bolts are such, that some engineers are induced to give a preference to the former; M. Seguin, amongst others, who continues to use them. A method was proposed some years ago of remedying the inconvenience of the alternate shrinking and swelling of trenails, by means of compression, or by forcing them, previous to being used, through conical holes."

The first trials gave favourable results, but it was soon found, when the trenails were taken from the moulds, that they were continually inclined to recover their original dimensions, and that after laying a short time in the stores, they again became subject to yield to all the *hygrometric* changes of the air, or medium in which they were placed.

The method recently adopted by Messrs. Ransome and May has, however, succeeded in overcoming the difficulty, and the wooden bolts thus obtained have become celebrated for their resistance to the influence of external agencies. The trenails are cut in the direction of the grain, out of a piece of heart of oak, and formed round to the dimensions represented in the cut, fig. 1, which is one-fourth of the real size.

Fig. 1.

Fig. 2.



" The trenail, thus shaped, is then forced into a mould with a conical aperture, whose interior dimensions are made to suit those of the prepared trenail. (See Fig. 2). It is next submitted, in the mould, to the action of steam, for about half an hour, at a temperature sufficient to effect a kind of fusion of the resin and of the sap, and this period having elapsed, it is allowed to cool."

" The wood, thus prepared, becomes reduced in volume to about 63 per cent. of its original size, and its transversal strength is increased nearly 50 per cent. The compression, however, is not quite permanent."

" We must call attention to the circumstance of the interior form of the mould, giving three different diameters to the trenail, so that it resembles two cones, truncated at different bases, but united at their top. The upper extremity, which rests on the foot of the chair, and forms the head of the trenail, is formed the largest, since this part necessarily requires to be of greater strength, in order to be able to support the blows of the mallet in driving. The slight alteration of shape which it undergoes, enables it also to serve the same purposes as an impervious cork, and thus prevents the soaking in of water, which might rust the chair. The diameter at A A, fig. 2, is less than at the top, and it is even about a millimetre (.039 of an inch) less than at BB, at the lower extremity of the trenail, which, when once firmly driven into its place, remains fixed there, by a kind of dovetail, which nothing can break. Any slight tendency to swell which might still remain in wood, thus prepared and compressed, would only increase the compactness of union between the wood forming the sleeper and the trenail, which thus forms one solid whole, perfectly homogeneous."

Whatever may be the relative advantages and disadvantages between the use of iron and of wood bolts, the former have been used on almost all the great lines of railway now existing, and the employment of trenails has not yet been sufficiently general to warrant the condemnation of iron pins. The iron bolts, known by the name of spikes or pins, are either round or flat-headed. The former are preferable, as the blows of the hammer fall exactly on the middle of their heads, which is not always the case with the flat ones. The heads of these pins, even when well manufactured, and of good quality, sometimes break off both from the blows in driving, and from the workmen striking the sleepers too violently with their rammers. The chair is then secured with iron spikes, in the same way as practised on the American railways.

Iron screws or bolts are never employed to fix the chairs, but they have been used to fasten the iron rails to the longitudinal sleepers, as before stated. The pins may be placed with the nut either above or below the longitudinal sleeper.

If the screw end of the pin and the nut are placed above the projecting parts, they are liable to be touched by the rim of the wheels, it therefore becomes necessary to give a greater height to the iron rail, than when the heads of the screws are sunk flush with the bottom of the rail. The worm of the screw is also liable to get rusted even in the interior of the nut, when the union is not perfect and the air and damp perfectly excluded. And if the worm once becomes rusted, the operation of screwing and unscrewing of the nuts is very difficult.

The ordinary pins are not used on the Great Western railway, but others, furnished with screw-heads for the exterior portion of the feet only, and screws with countersunk heads are used exclusively for the centre part exposed to contact with the wheels. If the nuts were placed below the longitudinal sleepers, the taking up and replacing of the iron rails would require too much time, as well as great care. Rails of the bridge shape have, however, been fixed in America, by means of pins, the nuts of which were placed below the longitudinal sleeper, and the heads lodged in the hollow interior of the rail. (See United States Rails, Plate 3.)

After all, a screw furnished with a countersunk head, or screw-bolts, appears undoubtedly to be superior to ordinary pins. Screws have been adopted on the Croydon Railway,* as well as on the Great Western.

The rails are fastened to the longitudinal sleepers by screws on the Haarlem and Leyden Railway, according to the plan of M. Baude; the extremities are also secured by two large pins, which pass right through the plank, and are fixed beneath by a strong nut. (See Plate 4.)

Iron spikes are used on the Heidelberg and Carlsruhe line, which possess one advantage over the screws, that of permitting the rail to expand and contract as its temperature increases or diminishes. They are likewise more easily and sooner fixed than screws, and the fastenings can be placed anywhere upon the side of the rail, unless they approach too near the end of the sleeper, or too near each other, when they are apt to split the rail.

The iron pegs which are employed to fix the chairs, and the spikes to fasten the rails to the sleepers, are either plain, as those on all the French railways, or *jagged*, as the spikes used on the railway from Haarlem to Leyden, &c. (See Plate 4.) The jagged spikes are capable of being fixed firmer than those which are plain, but it is impossible to withdraw them without tearing the wood.

The dimensions of the chairs vary with the weight of the rails, and the

* See Plate II. Second Series of Railway Practice.—*Tr.*

distance which they are placed apart. We propose to discuss this subject hereafter, in examining the relative proportions between the dimensions of the rail and the distances of the bearings of the supports, and shall limit ourselves at present to some observations on the shape of chairs.

The form requisite for the chair depends on the method employed in attaching the rail to it.

The rail is fixed to the chairs by iron or wooden wedges, as shown in Plate 5, so that in the event of the chair upsetting in any direction, it necessarily drags the rail with it. It is sometimes fixed by pins and wedges, when the chair is arranged in such a manner that it may incline a little either fore or aft, without the rail losing its position.*

The ordinary effect of the passing of the trains over the rails being to derange the chairs, either more or less; there is no doubt that in the system with the pins and wedges ("*George Stephenson's Plan*") there is a greater probability of maintaining the joints in good condition than in the common system of wedges; but the latter being so much simpler than the other, is almost universally employed. The former system has only been adopted on some of the railways constructed by Mr. George Stephenson, as that of the Manchester and Leeds, and the Midland Counties Railway, (Derby.)

The chairs are composed of a foot, which rests upon the sleeper or on the blocks, and the two projecting cheeks enclose the rail on each side. The foot and the cheeks being formed of one piece, each of the cheeks of the chairs, shown in Plate 5, is sustained by two shoulders, and the holes required for the bolts are placed between them in the foot. The cheeks of the chairs have one shoulder only, on the South Eastern Railway, as we have already stated, in order that the four holes of the two chairs may not be placed along the centre of the sleeper.

We perceive, by an inspection of Plate 5, that the side of the rail touches the cheek of the chair for a short height only in the direction of a vertical plane. By keeping the surface in contact of the smallest extent possible, the connexion is rendered much closer than if they filled the entire height of the cheek. The bottom of the chair is sometimes convex, so that the rail only rests on a point perpendicular to the centre of the line. This shape has been adopted principally where pins and iron wedges were used, in order to prevent the chair, when it happens to incline either fore or aft, from dragging the rail along with it; but

* See the 50lbs. to the yard, fish-bellied Rails, known as "George Stephenson's Plan," First Series of Railway Practice, Third Edition.—*Tr.*

this defect is not remedied by these chairs, so well as by those formed after "*George Stephenson's Plan*," for if we suppose that the rail rests on the top of the convex base of the chair, and the latter happens to get inclined, it cannot turn excepting round the bolt which is fixed, for the convex portion of the chair becomes arrested in its movement by the straight portions forming the bottom of the rail, and the bolt is necessarily forced out.

When thin iron wedges are employed, the cheek of the chair which receives the wedge is grooved, or otherwise has a projecting chamfer at the top, as those used on the Roanne line, and on the South Eastern, in order that the wedge should be secured in every direction. With the same view we have increased the space between this projection on the Versailles line (left bank), at one of the extremities of the chair. (See Plate 5.) So that the face of the chair, against which the wedge rests, is inclined to the line of the rail—i.e., the space between A A is of less width than B B. There are inconveniences with this system in practice which are sufficient to lead us to reject it, notwithstanding the advantages which it may appear to present in theory; the following are some of them. The rails on a line formed with two ways frequently slide onwards upon the straight parts in the direction which the trains run, which may be especially noticed after a long continuance of drought on railways where wooden wedges are employed. This arises from the force of the traction to which the rails are subjected, in consequence of the friction and the shocks of the wheels in passing over the joints, all of which give the rails a tendency to *move forward*, particularly when the wedges are dry, as they do not then secure the rails so firmly. The complicated effect of the friction at the curves and the slipping of the wheels, generally causes the rails to move in a contrary direction upon them.

In order to prevent as much as possible the displacement of the rails, such as we have just mentioned, the wedges should be uniformly driven towards the same direction that the trains proceed. The rails will be secured with much greater firmness by this method, than if the wedges had been driven in a contrary direction, and the labour and expense of repairs and maintenance diminished. This forms also a necessary precaution against the danger of accidents, for should a rail become displaced, the extremity being no longer supported by the chair, is liable to fracture. It is therefore unnecessary to provide for the admission of the wedges, by tapering the cheeks of the chairs longitudinally in the direction of the railway, either in one direction or the other; it is only necessary to round their edges in order to be able to introduce the wedges without tearing the fibres of the wood on the metal.

We have stated that the rails are fixed between the cheeks of the chairs by wooden wedges, also by pins and wedges formed of iron.

The wooden wedges are more effective fastenings, when used sufficiently dry, than iron pins and wedges. They do not fracture the cheeks of the chairs from swelling under the effects of moisture, as was feared before they had been tested by experience. The cheeks of the chairs often break in the operation of driving iron wedges or bolts, more especially if this is performed too violently, which accident never occurs with wooden ones. The displacement of the rails in the direction of the traffic is much greater with iron wedges than with the others, since, when once loosened, they afford no support whatever to the rail.

Wooden wedges have obtained the preference on all the railways constructed in France, and on a great number of those in England. The use of iron wedges has, however, been persevered with in Belgium. True iron wedges were used on the railway from Leeds to Selby, and tapered, in order that they should be in contact with the smallest extent of surface possible of the rail.

Wooden wedges are used either uncompressed or compressed.

The latter are generally adopted in England, as they effect a secure fastening, but we understand from Mr. Robert Stephenson that he did not employ compressed wedges on the London and Birmingham Railway until the way became consolidated by use, and the displacing of the rails had ceased to render it necessary to be constantly fastening and unfastening the wedges in order to restore the level or to replace the rails.

On the railways in the environs of Paris, that of Rouen excepted, the wedges employed are formed of uncompressed wood.

The wedges were dried in a kiln for the railway from Nuremburg to Furth. The compressed wedges have been used on the Rouen since the opening of the line. We have before stated our reasons for recommending that the seat of the rail be made of the same width through the whole length of the chair, after which we cannot do otherwise than advise the use of compressed wedges, by which the joining will always be properly maintained.

The wedges may be placed either on the inside, that is to say, between the rail and the cheek of the chair nearest to the centre of the rail, or on the outside between the rail and the cheek of the chair furthest from the centre of the road.

The wedges are placed on the outside on all lines that we have examined, that of St. Stephens to Lyons alone excepted, and for the following reasons:— When the wedge is placed on the outside, it can be carried a greater height, and preserved from decay by being covered with ballasting, but if it is placed within

the way, this cannot be the case, since the flanges of the wheels would rub against the ballasting, if not upon the wedge itself.

Another advantage is also obtained in placing the wedge between the rail and the exterior cheek of the chair, provided it is made of wood. It reduces the effect of lateral shocks on the cheek, which always take a direction from the inside towards the out.

The dimensions, and consequently the weight of the rails, as well as the size and weight of the chairs, ought to be proportionate to the distance which the points of support are placed beneath them, and the weight of the locomotives.

The proportions employed on the most important lines between these several parts are exhibited in the following Table:—

	Distance between the Points of Support.	Weight of Ordinary Chairs.	Weight of Joint Chairs.
Rails weighing from 13 to 25 kilog. per metre (from 27 to 51 lbs. per yard)	0 metre 90 (3 feet)	from 7 to 8½ kilog. (from 15 to 18 lbs.)	from 9 to 11 kilog. (from 20 to 24 lbs.)
Rails weighing from 25 to 32 kilog. per metre (from 51 to 66 lbs. per yard)	from 0 metre 90 to 1 metre 12 (3 feet to 3 feet 9 inches)	from 7 to 10 kilog. (from 15 to 22 lbs.)	from 9 to 14 kilog. (from 20 to 31 lbs.)
Rails weighing from 32 to 37 kilog. per metre (from 66 to 76 lbs. per yard) and upwards . .	1 metre 20 (4 feet)	from 9½ to 12 kilog. (from 21 to 26 lbs.)	from 12 to 16 kilog. (from 26 to 35 lbs.)

The weight of the rails, which is regulated by their different heights and dimensions, will be found in the Plates. (See the explanations of the Plates.)

Rails weighing less than 20 kilogrammes per metre (41 lbs. per yard,) are placed on supports at distances of 0^{m} 90 (3 feet) apart, and are too light for carrying the engines used at the present time on the great lines of railway; these locomotives weigh from eight to sixteen tons, the lighter having four wheels and the heavier six. We think that rails placed on supports, 0^{m} 90, (3 feet apart,) should be equal to 25 kilogrammes per metre, 51 lbs. per yard, if heavy engines are intended to be constantly used. The engineers of the railway from Strasbourg to Basle have adopted this weight.

We have found a weight of 7 kilogrammes, (15 lbs.) which we have mentioned as that of the ordinary chairs on the St. Stephens and Lyons Railway, too

little. The rails on this line being equal to 30 kilogrammes (61 lbs. per yard) in weight, and the supports being 0^m 90 (3 feet) apart. We should prefer the chair used on the Strasbourg and Basle line, which weighs 8.50 kilogrammes, (18½ lbs.)

We adopt a chair weighing 9·20 kilogrammes, (20 lbs.) for rails of 30 kilogrammes per metre (61 lbs. per yard,) as those on the Versailles Railway, (left bank,) and on the Orleans line, the distance between the supports being 1^m 12, (3 feet, 8 inches.) The dimensions of some of the chairs on the Versailles line, (left bank) could be reduced without inconvenience, as, for instance, the thickness of the sides of the shoulders, but it is not advisable to alter the height of the foot beneath the rail, although it may appear large, as this part of the chair is the most liable to break.

When the rail weighs 37 kilogrammes per metre, (77 lbs. per yard,) the supports are placed 1^m 20 (3 feet, 11 inches) apart, and it has been even tried to increase the bearings to 1^m 50, (4 feet, 11 inches,) but practice has proved this distance to be too great.

A chair weighing 9½ to 10 kilogrammes, (20¾ to 22 lbs.) appears too heavy for a rail of 36 to 37 kilogrammes per metre, (73 to 77lbs. per yard.) (See the chair used on the line from Paris to Rouen.)

In our remarks concerning the proportion between the weight of the rail and that of the chair, we have referred to *parallel rails* only.

If the rail is *fish-bellied*, the tendency of the chair to upset is a trifle diminished, since the height of the rail at the point of support is diminished, therefore the chair may be formed lighter, but we must recollect that the undulating rail occasions inconveniences so far exceeding this slight advantage that its use is almost universally rejected.

It has been already stated that on many of the railways recently constructed, the distance between the points of support has not been preserved uniform throughout the entire length of the line. The distances between the supports on the Rouen Railway are 1^m 12 (3 feet, 8 inches) at the joints, and 1^m 28 (4 feet, 2 inches) at the other parts. On those parts of the line from St. Stephens to Lyons where the rails have been relaid, the distances are 0^m 80 (2 feet, 7 inches) at the joints, and 0^m 90 (3 feet) at the other parts.

The distances are as follows on the Orleans Railway:—In the cuttings, and where the soil is good, the distances between the sleepers at the joint and those next to them are 1^m 0, (3 feet, 3 inches,) and between the ordinary sleepers, 1^m 25, (4 feet, 2 inches.) Upon embankments, and in those cuttings where the soil is doubtful, the distances between the sleepers at the joint and those next to them

is 0^m 75 (2 feet 5 inches), and the distance between the other sleepers is 1^m 0 (3 feet 3 inches).

The wrought-iron rails are usually 4^m 50 (14 feet 9 inches) long; those used on the Rouen line are 4^m 80 (15 feet 8 inches).

The scantling necessary to be given to the sleepers has been described in a former part of the work. The flat-footed champignon rail, or those used on the line from Hull to Selby (see Plate 3), also those laid down on the Croydon railway, upon longitudinal beams, may be considered excellent models of rails, formed of wood and iron, after the manner of continuous bearings, for the reception of locomotives.

The longitudinal beams on the Croydon line are 30 centimetres by 15 centimetres square (12 inches by 6 inches.) The sleepers on which they are laid are placed at distances of 3^m at the least (9 feet 9 inches) to 4^m 50 (14 feet 9 inches) at the most from each other, and have a scantling of 20 to 30 centimetres by 10 centimetres (8 to 12 inches by 4 inches).

Of the different patterns of bridge rails tried upon the Great Western Railway, and exhibited in Plate 3, the heaviest is the only one which appears to possess sufficient strength to support the powerful engines employed on this line.

These rails, weighing 31 kilogrammes per metre (64 lbs. per yard) are fixed on longitudinal beams, which are 38 centimetres by 18 centimetres (15 inches by 7 inches); the sleepers are placed from 3^m 0 to 4^m 0 (9 feet 9 inches to 13 feet) apart.

The Railway from Leyden to Haarlem is formed with a gauge of way equal to 2^m 0 (6 feet 6½ inches), which nearly equals that of the Great Western. Bridge rails, weighing 30 kilogrammes per metre (61 lbs. per yard), are employed, the longitudinal beams being 38 centimetres by 20 centimetres (14¾ inches by 8 inches); the transverse sleepers are 2^m 90 (9 feet 6 inches) long, and have a scantling of 28 centimetres by 15 centimetres (11 inches by 6 inches), and are set at distances of 1^m 0 (3 feet 3 inches) apart.

On a railway, formed of the gauge of 1^m 50 (4 feet 11 inches) from centre to centre, and intended to support locomotives of the ordinary weight, as the line from Heidelberg to Carlsruhe, bridge rails, weighing 23·50 kilogrammes per metre (47 lbs. per yard), are found sufficient. The longitudinal beams having a scantling of 25 centimetres by 15 centimetres (9¾ inches by 6 inches), and the transverse sleepers placed 1^m 50 (4 feet 11 inches) apart.

Some of the bridge rails, shown in Plate 3, are not high enough.

There have been experiments made to determine the theory of the strength

of champignon rails, and the dimensions corresponding to their maximum strength. The third edition of the English Treatise on Railways, by Mr. Nicholas Wood, contains several Tables of the strength of cast and wrought iron rails, but we do not think they possess sufficient interest to introduce in this work, and therefore refer such of our readers who may desire to consult them to the Treatise itself.

Professor Barlow has shown, by a deflectometer of his own invention, the effect produced by a weight passing in rapid motion over a wrought iron rail, and he has compared the same with the known effect produced by the same weight in a state of repose. He found that, with the chairs well fixed upon stone blocks or sound timber sleepers, the joints of the rails correct and true, and the roadway perfectly solid, that the rail, at the time of the maximum speed, showed a deflection to an extent very little exceeding that produced by the same load in a state of rest upon it, or equal to half the weight on two wheels; but the motive force would sometimes produce a deflection of the rail equal to double the weight of the load, where there were any imperfections in the way.

It follows, therefore, that until greater perfection is obtained in the construction of railways, we ought to lay down rails of double the strength required to resist the average force exerted upon them. Professor Barlow has calculated that 10 to 20 per cent. less than double would be sufficient, that is to say, a strength equal to 7 tons would be quite sufficient for a locomotive of 12 tons, as the weight is at present distributed.

And by using greater care for the future in the construction, which may be confidently expected at the present time, this amount may be still further reduced; or rather by continuing the same strength of rails, engines of 14 to 16 tons* may be employed with perfect security.

Professor Barlow applied this calculation to the simple T rail, and found the most advantageous dimensions for the bottom web.

The size requisite for the mushroom head, which varies with the weight of the locomotives used on the line of railway, has been determined from practice. Thus it was found that the mushroom-head rails of 17 kilogrammes per metre (34 lbs. per yard) employed on the Liverpool and Manchester Railway, were, after a short time, worn down by the engines.

The rails laid down on the Dublin and Kingstown line, which were furnished with a larger head (*champignon*), although defective, did not so soon wear out.

* See the different tables of the strength of wrought and cast iron rails, in the third edition of Wood's Treatise on Railways.

The simple parallel T rail of 25 kilogrammes per metre (51 lbs. per yard), and that of the Grand Junction, may be numbered among those possessing the most suitable dimensions. The size of the champignon at the surface where the wheels run is 0^{m} 056 (2¼ inches).

Experience has also shown that the height of the rails ought not to exceed 0^{m} 125 (5 inches).

Taking practical results, and comparing them with deductions of calculation, Professor Barlow determined in favour of the simple T shaped rail, and proposed to give it the following dimensions, varying with the distance between the supports:—

Distance between the points of supports.	Width of the Mushroom.		Width of the Stem.		Width of the Web.		Height of the Web.		Total Height.		Weight.	
											Weight per running metre.	Weight per running yard.
Metres Ft. Ins.	Met.	Ins.	Met.	Ins.	Met.	Ins.	Met.	Ins.	Met.	Ins.	Kilos.	lbs.
0.90 (3 0)	0.056	(2.2)	0.012	(0.472)	0.024	(0.944)	0.025	(0.984)	0.114	(4.4)	25.00	(51)
1.14 (3 9)	0.056	(2.2)	0.015	(0.590)	0.037	(1.4)	0.025	(0.984)	0.115	(4.5)	28 90	(59)
1.22 (4 0)	0.056	(2.2)	0.020	(0.787)	0.037	(1.4)	0.025	(0.984)	0.118	(4.6)	30.00	(61)
1.52 (5 0)	0.056	(2.2)	0.043	(1.6)	0.043	(1.6)	0.028	(1.1)	0.126	(5)	33.10	(67)

These dimensions are nearly similar to those now adopted on the principal railways, and represented in Plate 1, containing specimens of rails from different railways. We perceive, on examining this plate, that the width of the surface on which the wheels run is not made less than 0^{m} 056 (2¼ inches), excepting on the Orleans Railway, and on the railway from St. Stephens to Lyons.

The employment of the 1^{m} 52 (4 feet 11 inches) bearing is entirely discontinued at the present time.

The great lines of railway have been opened too short a period to determine the loss which the rails sustain by friction in a certain time, under given circumstances.

Mr. George Bidder concludes, from some experiments made by him, and by Mr. Dixon, on the Liverpool and Manchester Railway, that the reduction of the rail by friction would be 0^{m} 00028 ($\frac{1}{90}$ of an inch) annually, but he does not inform us of the amount of tonnage which passed over the rails experimented

upon, or weight of the engines, and many other circumstances which it is necessary to be made acquainted with.

It is, however, remarkable that one of us, M. Polonceau, had the diminution in the height of the rails on the line from Mulhouse to Thaun measured after the railway had been opened three years and a half, and on which four trains passed daily, when it was found to amount to a millimetre (·03937 inch), which gives 0^{m} ·00029 for the annual wear, or about $\frac{1}{80}$ of an inch, and the same result which Mr. Bidder has stated.

Notwithstanding the singular coincidence of these results, we merely state them in order that they may serve for the basis of future calculations, and without attaching greater importance than is necessary.

Some allusion to the Specifications for the manufacture of rails and chairs remains to be made. Perhaps the best plan will be for us to commence with a description of the processes of manufacture, which we have extracted literally from the "Treatise on the Manufacture of Iron," by Messrs. Eugene Flachat, A. Barrault, and Jules Petiet.

Sect. II.—*On the Manufacture of Rails.*

"The manufacture of rails employed in the construction of railways is an important branch of the business of iron-foundries at the present time, as it affords the manufacturers a ready means of employing all their iron of middling quality."

"All kinds of iron may be used for rails, provided it can be easily welded. That which possesses the greatest stiffness and durability is, however, the most esteemed. These qualities are found united in a high degree in the greater part of the pudlings made from coke castings, which alone are used, those arising from charcoal being too expensive, and since the latter find a better market when manufactured into iron for the purposes of trade.

"The manufacture of the different kinds of rails differs merely in the shape of the gates or grooves belonging to the cylinders, the general process in the operation remains the same in all cases.

"The forges appropriated solely for the manufacture of rails are rather larger than those used for general purposes, and should contain 600 to 700 kilogrammes (1323 to 1543 lbs.) of iron distributed in 3 or 5 bundles according to the weight of the rails in course of formation. The furnace is capable of burning 150 to 180 kilogrammes (330 to 396 lbs.) of coke per hour, and each furnace gives on an average 16 meltings in 24 hours, which produces 6 to 8 tons of

perfect iron. It is necessary to have 5 or 6 furnaces in operation to employ a set of rollers advantageously, and which require a good engine to work them.

"Hammers are not used in France in the manufacture of rails, but they are employed in some English foundries to weld the bundles together before they are passed under the cylinders. Thus, when taken from the furnace, the iron is first placed under the hammer, and receives a volley of 15 to 20 blows, it is then subjected again for a few minutes to the fire, and afterwards taken to the rollers.

"This method is very advantageous, and should have the effect of diminishing the number of bad rails by securing the proper welding of all the several pieces, forming the packets together."

A hammer of 3 or 4 tons striking 80 blows per minute is the usual apparatus employed in this operation, but the *tilt-hammer* produces still better results.

All rails, even the strongest, may be made in a series of cylinders of 0^m 35 (14 inches) diameter, and 1^m 00 (3 feet 3 inches) broad, but the use of cylinders of 0^m 45 to 0^m 50 (1 foot 5½ inches to 1 foot, 10 inches) in diameter, carrying a breadth of 1^m 20 to 1^m 40 (3 feet 11 inches to 4 feet 7 inches) and making 55 to 65 revolutions a minute, is very properly preferred.

"A set of cylinders answering this description would require an engine of from 60 to 80 horse power.

"The formation of a rail is generally effected by two gates or grooves, the first comprising the cylinders which shape the rail, and the second, those which finish it. Both are adapted to the same form of rail, and almost always require to be renewed when the manufacture is altered.

"The bundles adopted for large rails should always be formed of large dimensions. It is as well, in order to avoid overstraining the preparing cylinders, to form their gates (which should be at least five in number) in the shape of right angles, with their upper and lower faces parallel to the axes of the cylinders. The bundles are subjected successively to the action of the rollers, flatways and edgeways, and the bars composing them thus brought in good condition on every side for welding together. The preparing cylinders at Decazeville (see Plate 6) serve, at the same time, to prepare round iron of different dimensions; the cylinders have one series of lozenge-shaped channels, and two rectangular ones. The bars for the rails are first welded together by being passed four times through the first and second, and once afterwards through each of the following channels, which are lozenge-shaped. (See Plate 6.)

"Rails of small section may be formed in the ogee, or the square channels or diagonal preparing cylinders, like ordinary bars of iron; but when there are a

great many of the same shape to make, it is better to employ cylinders formed on purpose, because they always have the effect of facilitating and accelerating the operation."

" The finishing cylinders are formed with six grooves, whose shape assimilates by degrees to that of the rail which they are employed in making."

" The simple and double T rails, and those which are bridge-shaped, as the American rails, are always passed through flat, so that the width of the groove coincides with the height of the rail."

" As it is necessary for the facility of working that the iron should spread about 0^{m} 001 to 0^{m} 0015 ($\frac{2}{50}$ to $\frac{3}{50}$ of an inch), in passing through each of the grooves, it is therefore evident that each piece, when it enters the first groove of the finishing cylinder, should have a width equal to the height of the rail, minus 0^{m} 001 to 0^{m} 0015 ($\frac{2}{50}$ to $\frac{3}{50}$ of an inch), multiplied by the number of the grooves it has to pass through before it is finished, amounting to about 0^{m} ·005 ($\frac{10}{50}$).*"

" The depth is necessarily equal to the width, when the drawing cylinder is composed of lozenges only, or square grooves, placed diagonally, but when they are formed with faces parallel to the axis of the rail, they are disposed in such a manner as to give the bar a rectangular shape when it enters the first groove of the finishing cylinders, and the labour of the latter is diminished without increasing that of the preparing cylinders, provided proper precautions have been taken to give the packets of iron a rectangular shape."

" Upon a rail being passed through the finishing rollers, the first grooves perform all the drawing out. There should not be more than a small difference between the sections of the two last, since the metal becomes considerably cooled by the time it is passed through them, which renders it liable to *rent* on the surface, which would cause the rail to be rejected, independent of the excessive force that would be required in the engine.

" The pieces of iron pass through the preparing rollers twice, flatways and edgeways, through the first and second grooves, and twice in each of the others. The finishing rollers have five grooves, the iron being passed once through the first four, and twice through the last, which is called the finisher, care being taken to give it a semi-revolution after the first passage.

" The packets should be passed through the first grooves as quickly as pos-

* In manufacturing rails with engines of small power, the grooves are often considerably increased in size, which renders the grain of the iron very open, by which the layers welded together frequently separate after a time, and cause the destruction of the rails.

sible, in order that the iron may be welded together while it remains hot. A moving stage, provided with a hammer, is found very advantageous in facilitating this operation, by which the end of the bar is heavily hammered, upon being placed on the table of the preparing cylinder.

"When the upper and lower faces of the rail are straight, or convex and perpendicular to the axis, the grooves can be formed symmetrical in both cylinders, but they must be arranged so that each of them shall efface the small edge which would otherwise be left at the joint throughout the entire length of the bar where the two cylinders are in contact. (See Finishing Cylinders used at Terrenoire, Plate 6.) But when the face of the rail is inclined or on one side, it is generally better that the groove should be formed entirely in the lower cylinder, by which the faces are rendered much superior, and the rail has less tendency to spring when it comes out; which advantages fully compensate for the slight inconvenience resulting from the difference in speed of the rolling at the circumference of the two cylinders. (See the Finishing Cylinders used at Decazeville, Plate 6.)

"The rolling of rails requires a great number of workmen; those usually employed comprise the *chief roller*, the *drawer*, the *two receivers*, and the *two lifters*, and three or four more labourers are necessary to assist in presenting the pieces at the grooves and to lift them away from the top of the male cylinder after their passage through.

"Fish-bellied rails are first formed straight by the preceding methods. They are next passed through a vertical groove, of which the upper part is concentric with a male cylinder, while the lower is eccentric in its relation to a female one, whose diameter is such, that each turn renders the lower edge of the rail curved and of the form required.

"The guard iron of this groove is moveable round an axis, so that its extremity always fits exactly upon the larger cylinder.

"When the rails have a lateral groove, such as the rail employed on the Birmingham and Derby Junction, (see Plate 2,) it is finished in the horizontal grooves, whose width is equal to the highest part of the rail in its convex portion.

"The manufacture of bridge-rails is not more difficult than that of solid ones; it is only necessary to arrange the cylinders so that the iron shall be rolled equally in all directions. If the rail was formed of the proper shape at once, with the interior faces parallel, it must be evident that the cheeks would necessarily be much less compressed than the top and base, whereby the rail would consequently be defective. Therefore, in order to avoid this inconvenience, the workmen com-

mence by giving the rail an open form, like that shown at Fig. 11, Plate 6; and the sides are drawn together during its last passage, when the foot is brought parallel to the surface which is intended to receive the wheels.

"When the rail is passed through the finishing cylinders, it is placed on a cast-iron table (*plaque à redresser*), and dressed with the greatest accuracy to the shape required by means of wooden mallets.

"The rails are cut by a machine placed at the end of the dressing table, so that upon the last operation being finished, the end of the rail is cut before it has time to cool.

"The cutting of the rails is generally performed while they are hot by circular saws. Both ends are frequently cut at the same time in England, the distance between the saws, which are placed parallel, being equal to the length of the rail when finished and cold, *plus* a quantity equal to the amount which it contracts during the period of cooling. The length of the rails, however, is not always rendered the same by this method, as they are not all cut at the same temperature. The French Railway Companies, perhaps, attach too great importance to an uniformity in length of the rails. They begin by cutting one end of the rail, when it is allowed to cool, and the extremity remaining to be cut is afterwards re-heated and cut to the length required.

"The Railway Company should determine the method to be employed for this purpose, and it is important in all cases, unless a slanting joint is desired, that the end of the rail should be perfectly square, the proper accomplishment of which should be kept constantly in view in the arrangement of the saws with the rail. This apparatus is composed of two parts—one, which is fixed, consists of the *saw;* the other is moveable, and forms the *stage* on which the rail is placed, and which is contrived so as to approach the edge intended to cut the rail by an arrangement that causes the axis of the saw and the rail to be always perfectly parallel.

"The diameter of the *saws* varies in the different foundries from 0^{m} 80 to 1^{m} 20 (2 foot 7 inches to 3 feet 11 inches). They are fixed in two cast-iron discs, and fixed at the extremity of a shaft which makes 800 to 1000 revolutions per minute. Large blades possess the advantage of not wearing out so soon as smaller ones, also of being able to be re-set more frequently; but the latter are less expensive, and do not become so soon clogged, and are therefore often preferred. The teeth of the saws are turned back in some foundries, to allow of play and to render the operation easier. They endeavour to preserve their temper as long as possible by passing them through a trough full of fresh water during their revolution. The edges require great management notwithstanding these pre-

cautions. They ought to be changed and inspected after every 24 hours' work to ensure of perfect performance. It is necessary to have at least three or four extra saws for each apparatus.

" The *stage* for the rail is enabled to move in a lateral direction and parallel to its length by slides carefully adjusted. This plan is followed at the works of Decazeville, but more especially at the English foundries. (See the representations of *a double saw for cutting both ends of the rails at the same time*, Plate 7.) Since, however, this apparatus is both expensive and difficult to make, and but rarely answers the purpose, there is perhaps some reason for preferring the *pivot support*, of which we give a rough sketch in Plate 7. (See *a single saw for cutting the end only of a rail at a time.*) The rail is generally placed flatways on the stage, but it is sometimes fixed edgeways to reduce the lateral run of the carriage, and secure a right angle at the joint."

" When the rails are severed by a *cutter*, they are fixed at one end in a sort of vice, furnished with jaws, which embrace the rail horizontally, as shown in Plate 6. (See *vice for cutting the rails.*) The severance is accomplished by a sort of axe, which is struck heavily by a hammer. This method is generally employed to cut the second end after the first has been cut by the saw, but it would be better to employ the latter expedient for both."

" When the extremities of a rail are not both cut at the same time, it is necessary to re-heat the end remaining to be cut before commencing the operation. The heating may be effected in a forge fire, but a small reverberating furnace answers better, which should be furnished with four or five openings upon each face, corresponding exactly with the form of the rail. The bars are laid partly in the furnace and partly on a cast-iron support, furnished with a horizontal roller to facilitate their movements. Upon their being sufficiently heated, they are removed and cut either with the saws or by the axe."

" When the saws are set incorrectly, the ends of the bars are not taken off exactly perpendicularly to their axis, in which case it is necessary to employ the chisel and file to form them properly after they are cold. The same means are resorted to whenever any inequalities are left at the ends, which give the rails a bad appearance. This operation is generally found indispensable, and is practised in all foundries."

" Although the rails are dressed while hot on their leaving the rollers, upon a table formed of cast iron, where they are left to cool, still it is seldom that they do not require redressing upon their becoming cold. This operation may be performed in different ways. The plan followed at Decazeville, and at many other foundries,

is to place each bar on an anvil, furnished with grooves of the same shape as the rail, and by striking it with a heavy hammer the workmen form it to the shape required." (See *anvil for redressing the rails*, Plate 6.)

"A horizontal lever screw is very successfully employed at Creuzot Iron Works for this purpose. (See the details of this machine, Plate 6.) It is worked by three men, and all parts of the rail presenting inflections successively undergo the action of the screw. About a dozen blows generally suffice to accomplish the purpose required. If the rail is not expected to caste during the cooling, the cast iron table on which it is placed on quitting the saw is formed plain; but when the section of the rail presents greater density on one face than the other, as the Great Western Rail for example, the bar is placed on a table formed with a convex surface, corresponding to the form of the rail, and it is so arranged that the difference which it undergoes from the effects of contraction in cooling shall cause it to return to the figure required."

"The workmen either employ a strong chisel to break the refuse rails into pieces upon their being required for other purposes, or a vertical lever provided with a fly-wheel, which is more economical: the rail is placed on two small cast-iron brackets sufficiently close, with the point where the rail is required to be broken, which is previously marked by a notch placed in the centre between them, the force of the screw is then applied to it, and the fracture effected. The operation does not generally present any difficulties, since the iron constituting the rail is not sufficiently soft to bend rather than break. This apparatus is used at the iron works of Creuzot, where it answers very well.

"The bundles or packets of iron, which are employed to make the rails, being too heavy to drag along the ground, from the furnace to the rollers, are therefore drawn along on small trucks formed of cast and wrought iron, and run on two wheels; the bottom of the truck is a little higher than the table of the preparing cylinder, and is furnished with a cast iron hammer placed at its extremity, by means of which the workmen strike the end of the packet forcibly, and force it into the first gate or groove, which method greatly expedites the work.

"The transport of the rail after being drawn out is effected by a four wheeled truck, the bottom being formed of plate iron.

"We have now described the principal apparatus employed in the manufacture of rails, and we may add that it is very expensive, and costs considerable sums in maintenance, so that the expenses connected with these works can only be repaid where the amount of manufacture is considerable.

"The bundles of iron intended for the manufacture of rails are generally

composed of iron of two qualities, viz.: No. 1, iron which is employed for the interior, and No. 2, for the external covering, since it is essential that the upper part of the rail, which forms the surface on which the wheels are to run, should be as free from defects as possible; thus for every 1000 kilogrammes (2,205 lbs.) of rails manufactured there will be as follows:

1st,	1000 kilogrammes	(2,205 lbs.)	of rails suitable for reception on the line.
2nd,	100 „	(220 lbs.)	ditto, liable to rejection.
3rd,	100 „	(220 lbs.)	by loss in furnace.
4th,	125 „	(275 lbs.)	of cut ends.
Total weight	1325 kilogr.	(2,920 lbs.)	

Thus the bundles intended to make rails, 4^m 50 (14 feet 9 inches) long, and weighing 30 kilogrammes per metre (60½ lb. per yard,) weighing altogether 135 kilogrammes (297 lbs.), will require a weight of

	135 kilogrammes	(297½ lbs.)	for the Rails.
	17 „	(37 lbs.)	for Cut ends.
	13 „	(28½ lbs.)	for loss in furnace.
Total weight	165 kilogrammes	(363 lbs.)	

In making rails of 36 kilogrammes weight per metre (72¼ lbs. per yard), and 4^m 80 (15 feet 8 inches) long, as those on the line from Paris to Rouen, and like the bundles shown in Fig. 6, Plate 6, we shall have

	173 kilogrammes	(381¼ lbs.)	for the Rails.
	21.70 „	(47¾ lbs.)	for Cut ends.
	17.30 „	(38 lbs.)	for loss in furnace.
Total weight	212.00 kilogr.	(467 lbs.)	

The relative proportion between the weight of the iron forming the outside and that of the coarse iron, varies from ⅓ths to ⅓rd.

Thus, in making up a packet of 165 kilogrammes (363 lbs.) in 6 or 7 lengths, there would be about

	55 to	48 kilogrammes	(121 to	105½ lbs.)	of No. 2 Iron.
	110 to	117 „	(242 to	257½ lbs.)	of No. 1, or Coarse Iron.
Total	165	165 kilogrammes	(363	363 lbs.)	

The length of the bundle would be about 1^{m} 000 (3 feet 3 inches) for Rails of 173 kilogrammes ($381\frac{1}{4}$ lbs.), and there would be

	71 to	61 kilogrammes	(156 to	134 lbs.)	of No. 2 Iron.
	141 to	151 ,,	(311 to	333 lbs.)	of No. 1, or Coarse Iron.
Total	212	212 kilogrammes	(467	467 lbs.)	

And the bundle would be nearly 1^{m} 20 (3 feet 11 inches) in length.

" The greatest dimension given to bundles is a width of 0^{m} 162 (6 inches), with a thickness nearly equal. In order to ensure that the casings, carrying a width of 0^{m} 162 (6 inches), should cover the interior bars exactly, it is necessary that the latter should consist of bars of 0^{m} 108 and of 0^{m} 054 (of 4 inches and of 2 inches) in width, and 0^{m} 18 (7 inches), and arranged as shown in the Figs. 1 and 3, Plate 6."

" The bundles are sometimes composed, as represented in Fig. 5, Plate 6, for the purpose of giving a better quality to the edge of the champignon, in which case bundles of 165 kilogrammes (363 lbs.) are employed, as

80 kilogrammes	(176 lbs.)	of No. 2 Iron.
and 85 ,,	(187 lbs.)	of No. 1 Iron.
Total 165 kilogrammes	(363 lbs.)	

" The quality of the No. 1 iron, however, must be very inferior to require so large a proportion of the No. 2.

" A bundle of this size is formed of three sorts of iron, at the Decazeville foundry, viz.:

The centre of No. 1,	weighing 85 kilogrammes		(187 lbs.)
The lateral pieces of No. 2,	,, 25	,,	(55 lbs.)
The top and bottom casings of No. 3,	,, 55	,,	(121 lbs.)
	Total 165 kilogrammes		(363 lbs.)

" They have endeavoured, in some foundries, to use up the ends cut off by the saws, in the composition of the bundles, in consequence of which the iron did not become properly welded. These fragments are now generally used for making the coverings, together with the coarse iron."

" The casings being intended to form the surface for the wheels to run on, consequently require great care in their manufacture. The bundles employed in

forming them weigh as much as those employed for the rails, and may be composed of iron of the same dimensions; but as it is in general difficult to find bars of No. 1 iron 0^m 162 (6 inches) wide, it is necessary to employ the fragments of the casings of No. 2 iron, or to make them expressly, unless No. 1 iron, 0^m 135 (5 inches) wide, is preferred to be used as the bundle, Fig. 2, Plate 6."

"In order to render the ends of the rails available in the composition of the bundles forming the casings, it is necessary to make pieces of No. 1 iron of such a shape as to fill up the cavities at the sides of the rails, between the two projecting flanges. (See Fig. 7, Plate 6.) The packet is then composed in two different ways, either as shown at Fig. 2, by bringing in pieces of No. 2, 0^m 162 (6 inches) wide; or employing bars, 0^m 135 (5 inches) wide, of No. 1 iron, if the former is impossible. It is evident that the first method is the best, but it is also the most expensive.

"In the composition of these bundles, the casings are always of the same length throughout, but the interior bars may be composed of pieces of different lengths, placed end to end. The bundles employed in forming the rails, on the contrary, require to be made with bars, all of the same length.

"Fig. 8, Plate 6, represents the mode of forming a packet intended to be made of small bars of No. 2 iron, which are employed in the bundle, Fig. 5.

"The welding of the casings is made by a set of rollers of the same strength as those employed for the rails, and frequently in the same gates, but with the cylinders changed. Thus rails are made for a period of 18 days, at the works of Decazeville, and casings for the 8 following, and so on in succession. The set used at the Creuzot works consist of four gates, two of which serve for the rails, and the other two for the casings.

"The number of bundles placed together in a furnace to re-heat depends on the size of the bottom, and on the dimensions of the pieces. It is not, in general, loaded with more than three packets when of 210 kilogrammes in weight (463 lbs.), four of 165 kilogrammes (363 lbs.), or five of 135 kilogrammes (297½ lbs.)

"There are about fifteen or sixteen heats in twenty-four hours; thus a furnace will produce, on an average, 7 or 8 tons of finished rails in this period, with a consumption of 650 to 700 kilogrammes (1443 lbs. to 1543 lbs.) of coal per ton."

The following notes complete the amount of information derived from Messrs. Flachat, Petiet, and Barrault:—

A second furnace is made, in some foundries, next the principal one, where the bundles to be heated are commenced, by which the heat usually lost in the re-heating ovens, which is considerable, is turned to a useful account.

The use of the hammer, more especially the *tilt hammer*, to weld the packets, is doubtless very advantageous. We must, however, remark, that the perfection of the welding depends much less on the force of the compressing power than on the nature of the surfaces of the bodies to be united, and on their state of temperature. It requires to be varied according to the different qualities of the iron; the furnace, therefore, requires more attention than the forge, in order to effect good welding.

The iron employed at the works of Alais was found very difficult to weld, and it was not until after a number of trials that it was accomplished.

Presses are often substituted for hammers, since they do not cost so much in setting up, require less motive power, and are not so apt to produce splitting. The hammers also create shocks which injure the machinery; lastly, presses may be attended to by workmen at a less rate of wages than those employed in working the hammers. Presses, however, do not clear the iron so well as the latter.

Messrs. Flachat, Petiet, and Barrault describe a new machine lately employed in England for hammering, which, according to their statements, appears preferable in many respects to both hammers and presses. We are not ourselves sufficiently acquainted with this machine to be able to speak of its merits. We have noticed it in order that the engineers of new lines of railway may study, and either recommend or give instructions to the manufacturers respecting it, provided they approve of it, since no means should be neglected to obtain perfectly welded rails.

The rolling of the packets ought always to be commenced by passing them beneath the cylinders sideways, to bring the several pieces close together before they are compressed; and they should be subjected to a very slight rolling only in a direction perpendicular to their length.

The difficulties connected with handling a heavy bar in a red-hot state, and of placing it, when badly dressed, correctly in the seats in connexion with the saw, has led to the custom of cutting one end, directly the bar leaves the cylinders, to be almost universally rejected.

The greatest precautions ought to be taken to prevent the extremities of the rails oxidating when they are re-heated, preparatory to subjecting them to the saw. As the air which penetrates between the rail and the sides of the opening contributes greatly to this oxidation, the joints should therefore be welded with the greatest care. The derangement of the teeth of the saw is principally attributable to its contact with this crust of oxide of iron.

The saws are difficult to keep in proper adjustment and in good order for

working. The axis of the saw and that of the rail are rarely parallel, notwithstanding all the care of the setters; besides which, some of the parts are apt to get twisted on one side. An adjusting screw is very useful for regulating the portion of the rail in the supports.

During the operation of sawing, upon the end of the rail being half cut through, it becomes inclined, and its weight tends to tear away the part still remaining to be cut. The tool also follows the line presenting the least resistance, by which the section is rendered oblique. The end ought therefore to be supported until entirely cut through.

The teeth of the saws also get deranged, and the slightest twist on the side of a tooth becomes most injurious at every revolution of the wheel. The twisted tooth drags the saw out of the cutting plane, and makes a new furrow, and consequently a series of scratches, in an oblique direction across the rail. It is necessary to take out any twists in the teeth as soon as they appear. The teeth should be made a thickness of 0^{m} ·04 ($1\frac{1}{2}$ inches,) in order to enable them to resist flexion. It is further necessary to change the saws every twelve hours. The effects of work and friction cause a loss of from 0^{m} ·004 to 0^{m} ·005 (·157 to ·196 of an inch) per diem.

SECT. III.—*Minutes of Specifications for supplying of Rails, Chairs, Trenails, and Wedges.*

A.—*Minutes of Specifications for supplying of Rails.*

Amongst the means taken for obtaining good workmanship from the manufacturer, one of the most efficacious, doubtless, consists in imposing stringent minutes of specifications upon him.

We must, however, admit, that notwithstanding whatever pains may be taken in drawing this up, it offers but a slender guarantee if the Company should not select a respectable tradesman, one in a position to fulfil his engagements, and at the same time allow him a fair price for his work.

It often happens that companies are tempted by low tenders, and consequently cheated by the manufacturer, who cannot realize a profit except by supplying an inferior article. When this material is once badly manufactured, it is seldom that the necessary time can be allowed for replacing it.

The coercive and remedial measures provided in the minutes of specifications are always unavailing. The Company is besides exposed to a process of arbitra-

tion, and when recourse is taken to this, the judges, being averse to ruin the manufacturers, generally behave with great indulgence towards them.

We should, therefore, advise Companies either to apply directly to manufacturers of known standing, or to proceed to make a fair selection from among a certain number of them.

The conditions which ought to be stipulated for in the statement of specifications may be described as follows:

1st. The manufacturer should have a plan or model of the rail transmitted to him, bearing the Company's stamp, and a letter signed by the Engineer. He should form his cylinders of such dimensions, that the rails produced may be exactly similar to the rail represented by the model, or in the drawing.

2nd. The first rail manufactured ought to be sent to the Engineer of the Company, and the manufacturer should not be allowed to proceed until the Engineer has notified his approval of the sample.

This precaution having been neglected by the Versailles Railway Company (left bank), the Engineer consequently did not receive the sample until 400 tons weight had been made, through the carelessness of an agent, who absented himself from the foundry when the manufacture of the rails was commenced. The shape of the rail was not so correct as it ought to have been, but yet not sufficiently defective to warrant the refusal of the 400 tons which were ready. If the minutes of specifications had contained the above clause, the Engineer would have been informed in sufficient time to have had the cylinders modified.

3rd. The iron of the rails ought to be at the same time hard, stiff, and tenacious. Iron of a hard description is preferred for the construction of rails, which is that least esteemed for ordinary purposes.

Since iron bars resist the force arising from the power of traction in the direction of their fibres better than they do the effects of pressure, it is always desirable to place them in the works, so that the effect should be carried in their longitudinal direction; and it is especially necessary that the iron should be tenacious to resist this force.

It is impossible to obtain the above stated desideratum upon railways. The efforts of the motive power, however, tend to break the bars in a direction perpendicular to their length, producing at intervals a kind of vibration, the force of which varies with the weight and velocity of the trains, and this destructive effect on the rails is seconded by the friction arising from the wheels. It is subjected also to a particular kind of action, and of which there is no example in the other applications of iron to useful purposes. The bars forming a railway alone, are situated

under these circumstances—viz., that of being liable to be destroyed by exfoliation or scaling, and dividing into fibres, extending along in their longitudinal direction.

Iron of superior quality, and that which is considered best for certain purposes, is not therefore eligible for the construction of rails; while that which is generally rejected is, on the contrary, the most suitable. Thus the rails employed, some years ago, on the St. Stephens Railway, and manufactured with charcoal, although considered to be of excellent quality, were soon destroyed; while those employed on our lines in the environs of Paris were made of iron cast with coke furnaces, which lasted excellently well, though rejected for the purposes of construction and machinery.

4th. That portion of the rail on which the locomotives and wagons run, which, on those formed entirely of iron, constitutes the *mushroom*, being the portion most liable to wear and tear, ought therefore to be made the strongest, and the intermediate part of the rail, or that forming the *stem* in champignon rails, may be of inferior quality; thus, all the champignon rails used in France are required to be as follows:—The champignon of No. 3 iron, and the stem of No. 2. The rails employed on some of the English railways are composed entirely of No. 3 iron.*

The quantity of No. 3 iron to be used in the manufacture of rails should be determined by the minutes of specifications. This quantity and its divisions are dependent on the shape of the rail. It is generally made a third in double champignon rails. The bundles are then composed of No. 1 and No. 2 iron. No. 1 becoming No. 2, when the bundle is rolled, and No. 2 iron, No. 3. (See the preceding article on the manufacture of rails.)

We stated at page 43, that rails have been manufactured in England, with the champignon composed of hammered iron, and the stem rolled, but we observed that they were not united properly together in the rolling. Some difficulty is even found in joining the No. 2, and No. 1 iron properly. Some English engineers have given a preference to rails composed entirely of No. 3 iron, on this account, notwithstanding their greater cost.

5th. The upper layer or casing of the bundle for the single T rail, and the upper and lower casings of those for the double T, ought always to be composed of one plate each as shown by the figures. (See Plate 6.)

This condition not having been observed in the first rails manufactured in

* The force of flection to which the rails are subjected being changed into one of traction at their lower portion, it would be prudent to require that simple T rails should have their bases made of No. 3 iron.

France, many of them consequently split longitudinally in a vertical plane, and separated the two pieces forming the surface on which the wheels run. All our great foundries possess cylinders at the present time, capable of forming these coverings of one piece. It is, however, necessary to specify their employment, lest from motives of economy, and in order to work in the waste pieces, the manufacturers should form some part at least by the old method.

6th. The section of the rails at their ends should be exactly perpendicular to their axles. It is well known in laying down the rails that it is necessary to leave a certain space between the ends as an allowance for contraction and expansion. If the section of the rail is oblique to its axis, the rails may appear to be situated at a suitable distance apart, at the level of their upper surface, and yet be in contact below.

The greater part of the rails delivered to us for the Versailles line (left bank), were cut at one extremity only properly, which arose from that being cut by the saw and the other by an axe.

It is therefore necessary to describe that both ends of the rail shall be cut by the saw, or by some other efficient instrument. The manufacturer ought to guarantee the employment of the requisite machines.

7th. A proportion of $\frac{19}{20}$ of the rails forming the supply ought to be of the same length to a millimetre (·039 of an inch), $\frac{1}{20}$ may be received less, provided they are of a uniform length of 3^{m} 75 (12 feet 3 inches) to 4^{m} (13 feet).

It is important that all the rails used upon the straight portions of the road should be of exactly the same length, in order that the points of support may be at uniform distances, and that no delay should arise, or embarrassment, in selecting the bars when workmen lay down the way, or when they require to replace a bar that may become damaged during the working of the line.

It is necessary to cut some of the rails in order that the joints should be all normal along the curves. They are formed of various lengths accordingly. When the curves are of great radius, like those employed on the French lines of railway where great speed is employed, the point to be cut off is very trifling. The operation ought to be performed in the workshops of the company. They dispose them also as we shall hereafter explain, so that the number of rails to be shortened is inconsiderable.

If $\frac{1}{20}$ of the quantity of rails are received of less than the standard length, provided they are free from defects, excepting at their extremities, it gives the manufacturer an opportunity of getting such rails off his hands. These rails may be generally employed at the siding places, the workshops, &c.

8th. The rails should not present any kind of defect, such as cracks, dents,

or other flaws. These imperfections may be sometimes passed over when situated in the stems, but if they are found in the mushroom, the rails ought not to be received.

9th. The rail should be redressed, at the expense of the manufacturer, whenever necessary. We had all the rails for the Versailles Railway (left bank) made at the Decazeville foundry, and all those which were badly dressed at the foundry, or damaged in the carriage, were redressed in our workshops. The expense of carriage to the workshops ought also to be borne by the manufacturer. It is further prudent to include in his contract the additional labour of conveying the rails directly to the spot where they are required to be used.

10th. The quality of the iron employed for the rails may be tested by breaking them, but as it would be expensive to break a large number of rails, a mode of trial by weight is preferred, in which they are required to support a certain load. When there is reason to believe that the iron will not break, it is sometimes subjected to a blow from a rammer, or let fall upon some hard substance from a given height, in the same way as artillery axles are tested.

The Minutes of Specifications for the supplying of rails on the Government lines do not stipulate for testing by blows. We, however, think it is well to reserve a right to demand it. A very slight blow will sometimes have the effect of breaking a rail, which might cause a serious accident; and it is necessary to guard against such casualties as much as possible. It is needless to add, that no more than a few rails, taken at random from the whole supply, are tried.

The Government specifications state the weight which champignon rails, of 30 kilogrammes per metre (60½ lbs. per yard), are required to support, the rail being placed on supports at distances of 1^{m} 12 (3 feet 8 inches) apart. (See the Documents.)

11th. We may judge in some degree of the stiffness and tenacity of the iron by means of testing, but use alone can determine its comparative hardness, and power of resisting exfoliation. It is therefore necessary that the manufacturer should warrant his goods for the space of (one year) from the time of their being brought into use: the extent of this warranty being always fixed beforehand.

12th. The Company ought to reserve the right of placing their own agent in the foundry, to overlook the manufacture.

The interests of the Company require that it should be represented at the foundries during the course of manufacture, since the rejection of a large quantity of the supply would cause an incalculable loss of time, as well as money, as we have before remarked. It is therefore prudent to take steps to preclude the possibility of being forced into this course.

The Minutes of Specification ought moreover to stipulate—

The time of delivery, and the place where it is to be made.

The periods of payment.

A fine should be imposed on the manufacturer, if he does not make the delivery at the time and place specified, the extent of which fine ought to be in proportion to the loss sustained by the Company from the delay.

Lastly. It is necessary to name the arbitrators, or rather one arbitrator, in the Minutes of Specifications, who should have an unequivocal right of decision in every dispute between the manufacturer and the Company, without being bound by forms or processes, and who ought to reside near the works.

The price paid for the rails on the St. Germains, and on the railway from Versailles to Orleans, some years since, was at the rate of 42 francs (£1 15*s.*) per 100 kilogrammes (220 lbs.), and delivered at Paris, which is equal to 35 francs (£1 9*s.* 2*d.*) at the foundry.

The new rails on the St. Stephen's line were manufactured at the foundry of Terre-Noire at the rate of 36 francs, 75 cents, (£1 10*s.* 7*d.*) per 100 kilogrammes, (220 lbs.) The manufacturers took the worn out rails as well as the old rails, which they replaced at the price of 24 francs. (£1.)

The price of rails has since fallen, the supplying of rails for the lines from Montpellier to Nismes has been let at the rate of 32 francs, (£1 6*s.* 8*d.*) per 100 kilogrammes, (220 lbs.) taken at the foundry.

The rails cost less in Belgium, the price of 23 francs 90 cents, (19*s* 10*d.*) was paid on the lines of the section from Aus to the Meuse.

The iron used in France, for the manufacture of engines, costs one half as much again as that employed for rails.

The inspector intrusted with the reception of the rails ought to feel satisfied that the work will be executed by the time fixed; he should preside over the manufacture to see that the several clauses in the specifications are carried out.

He should direct his attention to the management of the upper furnaces, examine their conditions, anticipate the chances of any obstacles and impediments occurring, and take care that the number of puddling furnaces, and those used to heat the rail a second time, are sufficient for an average monthly produce, and in regular working condition.

He should see that the bundles of iron are composed of Nos. 1 and 2 iron in the requisite proportions, and provide precautions, so that during the night, or any other time when he is obligated to be absent, the proportions should remain the same.

He should never allow the top and bottom casings to be made otherwise than with one plate only, of the whole width of the bundle.

He should examine and see that the welding is perfect, especially at the ends of the rails, and should make it his business to detect any holes and flaws that may be sometimes concealed by iron or lead filings, and soldering, which may be hidden by a coat of red oxide of iron.

He should satisfy himself that the rails are of the requisite length, and that they are cut perfectly square at their ends.

He should also devote the greatest attention to the shape of the rails, and see that they are of the requisite form throughout. The surface of the rails on which the wheels run is frequently irregular, which ought not to be tolerated, since it prevents their receiving the requisite inclination on being laid. The inspector should direct the rails to be piled up in regular figures, in order that they may be counted quickly, to facilitate their removal, and to prevent their being changed at the time of removal. He ought, lastly, to send a monthly report to the chief engineer, stating,—

1st. The number of rails manufactured;

2nd. That of the rails to be received;

3rd. An approximate calculation of the quantity which will be made during the following month.

The transmission of these documents is a guarantee to the central administration of the vigilance of their agent.

B.—*Minutes of Specifications for the Manufacture of Chairs.*

The chairs, like the rails, should be exact copies of the original model, the first chair cast ought to be sent to the engineer of the railway and the manufacturer should not be allowed to proceed until he obtains a written approval.

Respecting the reception of the chairs—it is especially important, that the rail should lodge properly between the cheeks of the chair, and be in perfect contact with the same, and of the bottom upon which it rests; that the base of the chair, or the part intended to rest on the block, or sleeper, should be perfectly plain; that the holes which are to receive the pins should be of the given dimensions, and formed perfectly vertical. We were obliged to reject a great number of chairs on the Versailles line (left bank), on account of the holes being either too small or formed obliquely, and the surface of the base uneven.

The cast iron for the chairs ought to be of a grey colour, free from flaws, air holes, or other defects of the same kind. The grain ought to be neither too close, too open, nor too fine, or dense.

The French government, like that of the Belgian, have accepted of cast chairs for the government lines, of the first melting as well as those of the second.

The upper furnaces which produce cast iron of the first melting, being subject to variation during their progress of working, the castings made therefrom are therefore sometimes of different qualities. It is consequently difficult to obtain chairs of a uniform quality, and we must not forget that the fracture of one of bad quality, during the passing of a train, might occasion a serious accident.

If, therefore, chairs of the first melting are intended to be made use of, it is most important that a careful agent should be appointed at the foundry, who should constantly watch the furnaces, and cause the run to be stopped, whenever the metal appears bad, or of middling quality. An active *surveillance* of this kind is unnecessary for castings of the second melting, but the difference in price being so great between the castings of the first and second meltings, we should not hesitate to prefer the first at the present time.

Chairs are paid for by the kilogramme; the specification ought to fix the weight, which may vary within certain *maxima* and *minima* limits.

When they are less than the *minimum* weight, they should be refused; if, on the contrary, they exceed the *maximum*, the manufacturer should not be paid for the excess. (See Government Minutes of Specifications in the Documents.) It is very important that the manufacturer should be subjected to this condition, since it is easy to increase the price of the chair without much extending the given form. The addition of a small quantity to each of the chairs, although almost imperceptible, greatly affects the total weight.

The quality of the chairs is tested by breaking a certain number, taken at random from among the supply. Government has very properly given instructions for experiments to be made on the cast iron of which they are made, since there is reason to fear that they would otherwise be run with castings in hot air, and the iron, although of small tenacity, presents a satisfactory appearance when broken.

The tenacity of the metal forming the chairs may also be tried by placing therein the end of a rail, and wedging up between the rail and the chair, by means of a machine, until the chair breaks: the amount of pressure exerted being capable of being ascertained.

When a certain portion of the supply is decided to be of bad quality, one seventh, for instance, the engineer should have the power of refusing the whole supply, without being obliged to break a greater number of chairs, and the manufacturer ought to be liable to a fine, to be previously determined, by way of damages.

We were obliged to reject the entire supply on the line of the Versailles

(left bank), although we had ordered them to be made after an approved example.

The engineer of the line ought to require of the manufacturer a year's warranty for the chairs as well as for the rails; he should also reserve a right of sending an agent of his own selection to overlook the process of their manufacture.

The minutes of specifications for the chairs ought to contain the same relative articles concerning payment, place of delivery, &c., as that for the rails.

The chairs of the second melting on the St. Germains, the Versailles, and the Orleans Railways, were obtained principally from the foundry of Fourchambault, and were paid for at the rate of from 30 to 34 francs (£1 5*s.* to £1 8*s.*) per 100 kilogrammes (220 lbs.) The price of chairs at the last letting of the government contracts was 23 francs (19*s.* 2*d.*) per 100 kilogrammes (220 lbs.) for those of the first melting delivered at the yards of the Company.

C.—*Minutes of Specifications for the Pins.*

The minutes of specification for the bolts should state their size and weight.

They should be made of iron of the second quality, tested by bending them by blows with a hammer under an angle of 45°, and redressing them afterwards.

They ought neither to break nor crack.

The head of the bolt should form part of the same piece with the body; when they are only welded together, they part under the blows of the hammer, or during the passage of the trains.

Therefore a certain number should be tried when they are delivered, by striking their heads, or subjecting them to any process directed, to detach the head of the pin from the shank.

D.—*Minutes of Specifications for Wooden Wedges.*

It is highly important that all the wedges are made from a good pattern, which should be sufficiently thick and long to fasten the rails firmly in the chairs, and due length left to allow of their being driven up further when they get dry.

A certain number ought to be tried on their delivery, by driving them between the rail and the chair.

They ought to be made of dry wood, and as free as possible from knots and other defects. They should be cut from wood of straight and compact grain.

Wedges made of pithy wood, or of weak grained, shrink from the effects of

drought, which renders it necessary to refasten them frequently. They also frequently split under the blows of the mallet, and last only a little time. It is important that the wedges should not be cut out by the saw, as it reduces their consistence and tears their fibres, so that they are liable to be grazed against the sides of the chairs during the operation of driving.

The wood should therefore be split, but since this cannot be performed with sufficient uniformity for the process of planing, it is necessary that they should be first prepared.

The plan of driving the wedges by a hammer into a steel mould, furnished with cutting sides, by which they acquire a shape somewhat resembling that finally required, is found to answer very well. The wedges are afterwards finished off by the plane.

Wedges manufactured after this method, are worth 150 to 175 francs, (£6 5*s*. to £7 5*s*. 10*d*.) per thousand at Paris. Wedges, however, are more economically manufactured by machinery.

SUPPLEMENTARY NOTE ON BRIDGE RAILS.

Bridge rails are sometimes placed on cast-iron plates at each end, in order that they may rest directly on the sleepers at these points, otherwise they are liable to get out of a level at their extremities, in consequence of the unequal resistance of the longitudinal sleepers. The shocks arising from this cause, inconvenience the passengers, as well as act prejudicially upon the materials.

Although this arrangement allows of the rails being in perfect juxtaposition, yet it, nevertheless, presents serious inconvenience, which it is necessary to notice.

The vibrations on the cast iron plates being violent, the pins become shaken, and play is by degrees produced in the timbers, until at length they cease to hold the rails. The wood is too much injured to admit of the bolts being re-driven, as the holes are increased in size from the motion of the bolts, and therefore do not close again. It is difficult to replace them, even in any way, as the sleepers are generally found to be unsound under the extremities of the rails, and incapable of affording a hold to the pins.

The same inconvenience arises in replacing a rail which may have sprung, or in removing one that is worn out or otherwise defective, since the shocks are not broken by wooden wedges (placed between the rail and the chair), which form an easy safeguard, with ordinary rails, against all the inconveniences enumerated.

CHAPTER V.

OF THE LAYING DOWN AND MAINTENANCE OF THE WAY.

The laying down of the way is one of the most important operations in the construction of a railway, and requires the greatest care.

A road carelessly laid occasions considerable additional expense. It renders the motion of the carriages disagreeable to the passengers, and may be the cause of most serious accidents. We propose to point out, in this chapter, the necessary precautions that should be taken to execute the way with the requisite perfection.

The chairs usually employed in France, in fixing the rails, are nailed to the blocks, or the sleepers, in workyards appropriated for that purpose, before the laying down is begun.

This operation, which precedes the execution of the way, is known by the name of *shoeing*. The firmness of the rail with the block, or the sleeper, depends on the degree of care taken in the shoeing, and on the inclination of the chairs towards the centre of the road being constantly uniform. The surface of the rails on which the wheels run are usually perpendicular to their height, and the bases of the chairs (excepting at the changing places, see Plates 15, 18, and 21) formed square and level; the rails, therefore, necessarily derive their requisite inclination from the sleepers. It is generally accomplished by the workmen charged with the shoeing, notching the sleepers to the proper slope. The *shoe*, or *chair*, is then placed in the notch, which is proved by the *gauge for fixing the chairs*, shown in Plate 10.

This gauge, as we may observe by studying the Plate, is composed of two ends of rails, fixed by screws to the extremities of an iron bar. The length of the bar between these pieces of rails, should be made exactly equal to the distance between the two opposite rails of the way, and the upper surface of the two ends of the rails ought to have the same inclination towards the middle of the bar, that the rails are required to be laid to, in reference to the centre line of the way.

When the gauge is used, a chair is connected to the rails at each end, secured by a wedge in the usual manner as those on the line. The bases of these

chairs are then placed on the sleeper to be shoed, in such a manner, that the distances at each extremity of the sleeper are nearly equal, when the notches are marked. The gauge is now taken up, and the workmen shape the notches by the eye; and when they have made the necessary inclination, the gauge with the chairs is again tried, until they feel assured of the chairs resting properly in their places. The workmen next bore the holes for the bolts, keeping the chairs in their places at the time, and finish by driving the pins; upon which the wedges are removed, and the gauge taken away.

This operation is generally done by two men, who work together, one at each notch; and by the system of *task-work:* when they are not overlooked, they often endeavour to save time by neglecting to finish off the notches made upon the first cutting, if the chairs fit tolerably well. The *heavy* blows of the hammer also twist the bar of the gauge in driving the pins, unless it is very thick; if, however, it resists, they take out the wedges and finish by driving in the pins after they have removed the gauge. The chairs, therefore, have neither the distance nor the inclination required. It is therefore necessary, before paying these workmen, to examine each of the sleepers that are shoed, and prove them carefully, or a large number taken from among them, and it is advisable, in order to prevent delays, to place the workmen under the inspection of a sharp overseer.

The gauge ought to be strongly formed, the intermediate bar being sufficiently thick to prevent the workmen altering its inclination, and the ends of the rails should be adjusted by strong screws, firm enough to prevent any play. The gauge requires to be tested, not only when it is received from the hands of the maker, but very often during the period of being used.

We have observed sleepers laid on some railways in England, with the notches only formed upon them, the chairs, pins, and rails having been put on afterwards. This plan is more simple than that which we have just described, since it is not possible to place the whole of the sleepers perfectly square, although it is requisite when they are shoed beforehand. The rails, however, never occupy the spaces left for them in the chairs precisely, when it is followed, but take different inclinations, notwithstanding the notches having been properly cut; for in taking up the models from the sand, when the chairs are moulded, irregularities are always left, and the chairs, from other causes, are not always exactly alike.

We may therefore presume, that laying down the road in this manner will render it less regular in character than when the chairs are adjusted on the sleepers previously. But viewing it in another point of view, we see that ma-

chinery can be employed for cutting the notches, so that a great number of sleepers may be cut at the same time, without fitting the chairs, which is inapplicable in the former case, by which a great saving would be realized.

It is seldom that all the notches are regular, whatever plan may be pursued, from which serious variations arise in the inclinations of the rails. Perhaps it would be more advantageous to give a certain inclination to the base of the chair, and merely to fix it upon the surface of the sleeper, after the same was properly dressed.

The shoeing is done either by *the day*, or by *task-work*. Two skilful workmen can shoe from 40 to 50 sleepers in a day of 10 hours, who are paid at the rate of 15 to 20 cents per sleeper; so that their day's work would amount to 8 francs, (3*s*. 4*d*. each.)

The rails intended for the permanent way should be re-dressed by the manufacturer, whenever they are bent, whether delivered so or caused by being used upon the earthwork. This operation, which should always precede the shoeing and laying down, may be performed with the rails either heated or cold, by hammers. The rails are always heated previous to undergoing this process on the Versailles line (left bank); but the opposite plan is pursued on the Strasbourg and Basle Railway, the rails being always cold when it is performed. We think it as well to re-heat the rails when the weather is cold. The *Horizontal Screw Lever* represented in Plate 6, and before alluded to at page 74, is sometimes advantageously substituted for the hammer.

The direction and height of the rails should always be correctly indicated by means of pickets placed along the centre of each line. These pickets ought to be placed closer upon the curves than in the straight portions. The surface of the head of each picket ought to correspond with the proposed level of the rails.

The workmen should level the ground before commencing these operations, and ram that part of the ballasting upon which the sleepers are intended to be laid. The latter being then placed on it, should be beaten down in the most careful manner, for since the soil is newly laid and hard, the sleepers consequently rebound at every blow of the rammer, by which the pins are liable to be jerked out of the chairs.

The sleepers being thus laid on the soil, and the rails fixed in the chairs, they are brought to the requisite level by packing the ballasting beneath them with the wooden mattocks shown in Plates 8 and 9.

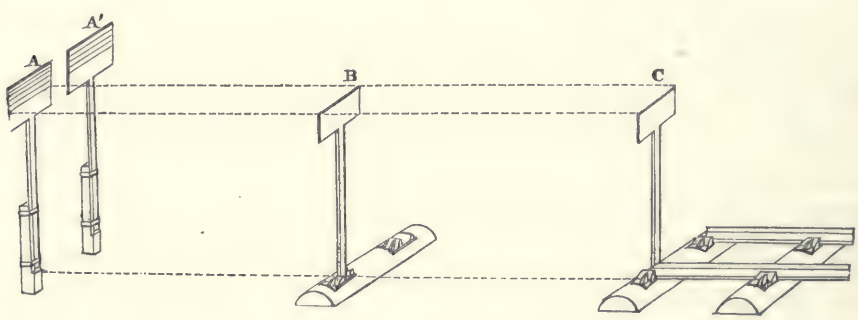
In performing this operation, also in that of ramming the ballasting under the sleepers previous to laying; it is necessary to manage so that the earth at each end

of the sleepers, for a distance of 40 centimetres (1 foot, 4 inches), should be packed firmer than in the middle; for if this precaution is neglected, the road will soon lose all its stability. The trains, in fact, press directly on the ends of the sleepers, but indirectly only upon the middle portions; so that if the resistance is made equal throughout the entire length of the sleepers, the middle portions alone are soon compelled to sustain all the weight, as the soil settles from beneath the extremities; when the sleepers consequently bend at the passage of every wheel in the train, and shake the soil away at the ends, and only settle by throwing off the ballasting, which covers them, until the evil increases to such an extent, that the road soon loses all stability.

The small level shown on the Plate last referred to, is employed in laying the way, and is used in the following manner:

The men commence by sticking iron pickets into the ground before them, and in the direction of each line of rails, the projections at their lower extremities being made on a level with the pickets placed along the middle of the line, which we have already alluded to, that is to say, at the level of the surface of the rails.

Two levels, A A, are placed on these projections, and fixed to the pickets in a vertical position. The levels are painted on each side, and in two colours, the lower part white, and the upper red or black.



The workmen carry two other levels in their hands, painted one colour, the height of the one at C (see cut) being equal to that of the level A, from its foot to the top of the white part. The height of the other, B, is equal to that of C, with the height of the rail added to it.

The laying down of the way is carried on by the foreman taking the level C, and placing it on the end of the last rail of the portion already laid; he causes a joint sleeper to be laid at the distance of one rail, and regulates its height by the level B, which one of the workmen holds at the base of the chair; the lineal

distance is given by means of a cord. The intermediate sleepers are afterwards laid down by a deal rule, which ought to be of the same length and height as the rail; they then beat them down, drop the rails into the chairs, and drive in the wedges.

Upon several rails being thus laid, and temporarily wedged, they verify the direction of the line; and if the work does not appear sufficiently correct, they modify it, by forcing the sleepers by levers, to the right or to the left of the centre line of the way, as may be necessary. They also regulate the height of the sleepers, and finally adjust them by packing the ballasting beneath, by means of rammers and mattocks.

The layers employed use a piece of plate iron, of a certain thickness, to measure the distance required to be left between the ends of the rails; this space ought to be 4 millimetres (0.157 inch) in winter, and 2 millimetres (0.78 inch) in summer.

The rails being securely laid, the whole is finished by laying ballasting sufficiently thick to effectually cover the sleepers, and to allow of ramming in the middle of each line, and in the space between the two lines of way. This additional coat of ballasting prevents the sleepers rotting by the alternate moisture and drought, and preserves sufficient humidity in the lower layer to maintain proper consistence. The convex portions, which may appear superfluous, is soon used in the maintenance of the way.

We cannot dwell too much on the advantages of ballasting the road properly, not only as a means of diminishing the expense of maintenance, but of rendering accidents less frequent and serious.

If the road is not properly ballasted along the curves, the sleepers are liable to get displaced laterally, which may have the effect of throwing the trains off the rails, and the consequences are more serious when the ballasting is bad, since the latter forms the best medium of opposition whereby to arrest the progress of the wheels. In the event of a locomotive or a carriage running off the line, the ballasting stops them gradually without causing any violent shocks, and consequently, risk of danger.

If the layer of ballasting is not sufficiently thick, the wheels of an engine or wagon which may have run off the rails, would soon be broken to pieces by the shocks arising from striking against the sleepers.

In laying the rails along the curves, the outside rails of each line are elevated above the level of the inside ones, for the purpose of counteracting the centrifugal force. The additional height necessary to be given to the exterior rail above the

interior, depends on the radius of the curve, and the general velocity of the trains. Where the trains travel at high velocities, it should be about 2 centimetres (0.787 inch) for curves of 1200 to 1500 metres (1312 to 1640 yards) radius.

It is prudent in laying rails upon an embankment, to keep the rail on the side next the slope a little higher than that next the centre line of the road, as the earth settles most on this direction, and unless this precaution is taken it would be frequently necessary to take up the way.

In each of these cases that we have just referred to, in which the rails are required to be placed at different heights, the lower rail should always be laid at the regulated level of the line.

The laying down of the way upon the constructive works ought to be carefully studied. It is especially necessary to interpose a layer of ballasting, of suitable thickness, between the road and the masonry, in order to guard against the effects of vibration. It is equally requisite to place a layer of ballasting upon the bridges and timber viaducts. This dead weight affords stability to these descriptions of works, which is very necessary, and it facilitates the re-dressing of the road.

If rails are placed on timber bridges, and laid directly on the boards, the line inevitably gets out of order by the play of the wood-work, and it is soon brought into a very bad state. The chairs and fastenings of the rails get out of their places, and the repairs are rendered very difficult.

The laying of ballasting upon wood-work also possesses the advantage of preserving it from fire, to which it is liable from the occasional fall of inflammable particles from the engines, more especially during the dry summer season.

They have replaced the rails upon some artificer's work on the railway from Strasbourg to Basle by square bars of iron, screwed to the longitudinal sleepers; the pressure of the trains being consequently distributed over a very small surface, consequently crushes the wood beneath the rails, and since the latter is also exposed to alternate moisture and dryness, it soon loses its consistence, whereby the screws which the wheels pass over are rendered ricketty, when it becomes necessary to replace them with bolts. The employment of bridge-rails, according to Mr. Brunel's system, would be more advantageous in this case, as is done on the Rouen line.

The laying of the way is performed either by the day or by task-work, in gangs, generally composed of eight men, viz. a foreman, and seven labourers. There is reason to fear that the work cannot be executed with the requisite care when performed by task-work, as mere labourers, who generally undertake it, can-

not be considered responsible. It is impossible to guard against their negligence by making them pay the expense of altering the work. The line also soon gets out of order, especially where laid on earthwork, from causes perfectly independent of the degree of perfection with which the road is laid, and which it is impossible to guard against. It is therefore very difficult to define the conditions to be observed in keeping the road in order in the specifications. We may state that notwithstanding these great difficulties in the mode of executing the laying down of the line by taskwork, it is generally preferred. It is important to subject the workmen to a rigid surveillance.

The price varies with the localities; we have paid the foreman at the rate of 4 francs (3*s.* 4*d.*) per day, and the labourers 3 francs (2*s.* 6*d.*) The price for task-work is at the rate of 75 cents per metre (7*d.* per yard) for each line of rails, comprising the transport of the rails and sleepers from the workshops on the way (*coltinage*) to distances of 500 metres to 600 metres (546 yards to 656 yards), which is accomplished by wagons pushed along by the men.

The chief foreman on the line from Strasbourg to Basle receives 3 francs (2*s.* 6*d.*) and the labourers 2 francs (1*s.* 8*d.*) per day, and the task-work is paid for at the rate of 42 cents per metre (4*d.* per yard) for each way, the sleepers being forwarded along the line to them, as well as the rails, and the levelling of the ballasting was paid for separately.

The foreman was paid 4 francs (3*s.* 4*d.*), the under-foreman 3 francs (2*s.* 6*d.*), and the assistants 2 francs 50 cents (2*s.* 1*d.* per day) on the line from Lille to the Belgian frontier, and the laying amounted to 44 cents the running metre (4½*d.* per yard) for each way. (See the Documents.)

It is calculated that a gang, well supplied with rails and sleepers, ought to lay 50 metres (55 yards) of one line of rails in a day of 10 hours.

It is as well to omit the supply of the ballasting in the contract with the workmen, as it is unnecessary to spread more ballasting than is absolutely required to carry the sleepers. The remainder, as we have already stated (at page 35), ought to be conveyed in wagons. A list of the tools required by a gang of workmen will be found in the Documents, together with their cost.

Mr. W. Cubitt, the engineer, has adopted a different plan on the South Eastern Railway from that which we have given. The following description of the method is extracted from an article by Mr. Manby, and inserted in the "Railway Journal":—

"Mr. Cubitt has employed sleepers on the South Eastern Railway, differing in form from those usually employed. They are made of a triangular shape, by

taking two diagonal cuts of a saw through beams 30 to 35 centimetres (12 inches to 14 inches) square, of northern fir.

" These sleepers are placed with the angular edges below, which affords them as large a base as those of a rectangular form, and containing twice the quantity of timber. It also permits of the ballasting being packed with greater precision, by which the level of the road is maintained without deranging or taking up the way.

" The beams employed originally on the South Eastern line being merely cut by the axe, Mr. W. Cubitt had them re-dressed and trimmed up at the places where the chairs rested, which operation was performed by the hand. Upon the sleepers being thus prepared, two lines were covered with ochre, and held firmly at the parallel distance of the rails, and unless the lines touched throughout, and showed by the traces left that the contact was perfect, and that the requisite accuracy was obtained, the sleepers were laid aside, and not used.

" Upon the sleepers being dressed, and one of the holes bored in each, they are placed in the soil. The chairs are then fixed upon them, and the bolts corresponding to the holes are driven in, upon which the rail is placed in the chairs, and upon the sleepers being finally fixed, the wedges are driven permanently into each chair.

" The wedges are formed of deal, and compressed by steam, like the trenails, in moulds properly prepared, but the diminution is limited to *one-fifth.*

" By the mode of operation which we have just described, one of the rails intended to form the way is placed in its proper position, and the action of driving the wedge forces the chair, so that its hold on the rail is rendered perfect. The hole required to place the second trenail is then bored, which fixes the other side of the chair.

" The operation of boring the holes is conducted in the following manner:—A portable instrument, standing upon three feet, is lodged upon the sleeper. It consists of a tube, the end of which is introduced into the hole of the chair, which is about 4 millimetres (0·157 inch) less than that of the trenail in diameter, and which it fits exactly. Upon the instrument being adjusted, an augur is set to work within it, and a hole bored in the wood, which is necessarily vertical and concentric with that of the chair. Like the tube, it is 4 millimetres (0·157 inch) less in diameter than the trenail which goes into it. There are two trenails driven in at the inner side of the joint chairs.

" In laying the second rail, the chairs are placed nearly in their exact situations on the sleepers, with the rails within them and the wedges driven.

" The rail is arranged in the correct position by means of an iron gauge, which tests the distances and fixes the rail between each chair. The position of the rail being thus determined with the requisite precision, the holes are bored for the second chair with the instrument, in the same manner as the second hole of the first was formed."

The engineer superintending the line ought to satisfy himself that the gradients are correctly laid off, and that the curves are properly described.

That the sleepers laid along the straight portions are perpendicular to and in the curves *normal* to the axis of the way.

That they are laid at the stipulated distances.

That the width of the road is uniform throughout.

That the inclination of the rails is also uniform and constant.

That the vacuities left at the joinings between the ends of the rails are neither too great nor too small.

That the surfaces of the rails on each side of the centre of the way on which the wheels run are exactly on the same level as the straight portions of the line.

That the exterior rail of all curves is elevated above the level as much as the radius of the curve and the degree of velocity of the trains require.

That the wedges fasten the rails firmly, and do not penetrate too much before the chairs, or present the least obstacle to being driven home when they become dry.

That the trenails do not get detached when they ram the sleepers.

That the ballasting is sufficient.

The maintenance of the way of a railway should be kept in order by gangs of workmen, who require to work together repeatedly before they act efficiently.

These gangs should each consist of a foreman and four men, taken exclusively from among the layers, who should trim and level the way, and perform all the repairs that are required.

There should be guards placed at intervals along the line, who should act as the police of the road, and make examinations after the passage of each train whether any part of the road is injured or deranged. They should also fasten any wedges which by any means whatever may have got loosened.

The number of road guards employed to watch the line varies according to the plan of the railway and the number of level crossings entrusted to their surveillance.

Respecting the number of workmen requisite on lines of railway. The number should be considerable, especially at the first opening of the line, if the

earthwork is subject to much movement. They may be reduced, after a certain period of time, to one or two layers for every kilometre (1094 yards), where the works have been executed with the requisite care, and the road is well ballasted.

The road of a railway ought not to be neglected for an instant, as the least damage causes the greatest injury to the *material*, and soon increases if not immediately remedied.

The road ought to be repaired, especially before the season of the greatest drought, and previous to the setting in of the frost.

If the ballasting is removed from the road during the dry season for the purpose of repairs, the small degree of humidity left in the lower layer is lost, and it accordingly loses its cohesion, and runs away beneath the sleepers. The earth along the road becomes so indurated that repairs are impossible to be made during the prevalence of frost, and the shocks which the *material* receives are more injurious in severe frosts than at any other time, if the way is not well dressed. In cases where the frost is not sufficiently hard to suspend all operations, so that the workmen are induced to pack ballasting under the sleepers, and it becomes frozen during the process, then the way does not remain in a sound state after the period of the thaw.

Earthworks settle unequally, and it is most important that they should be continually examined, to be sure that the proper difference of height between the rails of the outside and inside curves is maintained. It would be highly dangerous if the rail forming the outside curve become reduced to a less height than the inside one, (instead of greater,) from the effect of settlements.

As the sleepers require to be frequently taken up for a few years following the opening of a railway, we must not, therefore, omit to distribute sufficient quantities of ballasting at various points on the line. It is also necessary to have spare rails and sleepers distributed along the way, which should be kept locked up wherever possible, not so much for the sake of security as to prevent their getting into the hands of evil disposed persons, who might employ them for malignant purposes. Sleepers with chairs attached to them have been found placed intentionally across the rails, both on the Versailles line (left bank) and on the railway from Strasbourg to Basle, the moment after the switchmen had turned the rails, and when a fresh train was on the point of passing.

We may remark, that no special law exists in France for the prevention of these crimes, by which the lives of the public are exposed to serious dangers.

This class of offences is more frequent than might be supposed, as the punishment to offenders is very trifling. Now that the means of preventing accidents on

railways appears to engage the attention of government, it is to be hoped that this omission will be soon supplied.

We shall terminate these remarks on the maintenance of the way, by pointing out a precaution which should be observed when the way is taken up, which, although it may appear trifling, is, however, of practical importance.

The workmen have a practice, when they take up the way for the purpose of repairs, of only turning up the portion of ballasting next the sleeper to be removed, the rest of the ballasting remaining unmoved. The latter is, therefore, denser than that which has been repaired, whereby the rain filters under the sleeper, and consequently deprives it of its stability. It is therefore necessary, when a sleeper is removed, to instruct the workmen not only to move the portion of ballasting at the two sides, but also that situated along the middle of the line.

CHAPTER VI.

OF CHANGING PLACES—TURN-TABLES—SLIDE-RAILS FOR CHANGING THE LINE—LEVEL CROSSINGS AND FENCINGS.

SECT. I.—*Changing Places.*

THE changing places upon a line of railway are composed of two distinct parts:—

1st, The *switches*, or moveable portions, which are placed at the points of junction of the two lines, and intended, by their movement, to direct the trains to either one branch or the other.

2nd, The *crossings*, which are situated at the spots where one set of rails is intersected by another and cut through, in order to allow of a passage for the flanges of the wheels. This portion is generally fixed in its position, but is, however, sometimes constructed so as to be moveable.

The different systems employed for changing the way may be reduced to three distinct classes, which are determined by the manner in which the switches operate:—

1st, When the line of way is broken, and the switches are formed by the portions of the road displaced, as shown by the plan connected with the section C—D, Plate 20, (employed on the St. Germains Railway.)

2nd, Those in which all the several parts of the way are fixed, the switches serving as guard-rails to direct the trains, which are called *check-rails*. See Plate 16, (employed on the Versailles Railway, left bank.)

3rd, When the changing places are contrived so that the engines and wagons pass along one moveable rail only, as shown at Plate 11 (Mr. Stephenson's switch rails), or like the changing places employed for temporary works.

The changing places of the first kind, in which the switches consist of the portions which become displaced, permit of the passage of the trains with less abruptness, and present the least resistance of any, more especially if the switch rails are made of great length. Great danger, however, arises if the switch rails

are badly set: a train passing along it in its course from one of the branches towards the single line, is sure to get off the line. Although such an accident, if the velocity is not great, may only slightly injure the engine and train, yet it always causes interruptions to the traffic, and often breaks the moving rods which connect the switch rails.

The changing places furnished with the check-rail are not so gentle as the others which we have already alluded to. The speed of the trains, therefore, should always be diminished when these are adopted. This system is much safer than the first, since the carriages are never liable to get off the rails when proceeding in either direction, provided, as we shall show hereafter, that the speed is always diminished, and the changing place judiciously placed. The train can do no more than pass on to a different line from that which it ought to have followed, or pass over the switches, which gives the engine and train a slight shock, but is perfectly free of danger.

We may add, that although these crossings effect a more sudden deviation than the others, they will afford an easy passage, when correctly laid out, and switches of sufficient length are employed.

It has been proposed to use changing places with moveable rails (the 1st kind), on such portions of the line as are traversed at great velocity, and *check-rails* (the 2nd kind) in connexion with the stations where the communications are so much more frequent in each direction, whereby the switchmen may be rendered more liable to mistakes; but we are not advocates for this arrangement.

It is especially necessary to endeavour, in the construction of railways, to reduce the causes of accidents. It forms one of the principal objects to which we have directed our attention, and should never be lost sight of. Accidents are always injurious to the *material*, interrupt the traffic, and are the cause of greater expenses than is generally supposed, independent of the loss of life which they may occasion.

Taking these facts into consideration, we are therefore of opinion, that changing places with *moveable rails* should only be used on lines which are traversed at great velocity, and in certain situations only, as we shall hereafter point out. They lose even the only advantage which they possess over changing places formed with *check-rails*, or that of presenting a less sudden deviation, when the latter are placed in such a way that the trains passing in one direction cannot be exposed to take an oblique course.

Let us observe, finally, that when trains pass along an oblique line by means

of a changing place, they ought always to go slowly, consequently the resistance encountered, although more perceptible in the changing place formed with check-rails, would never be very great.

Changing places of the first kind have been advantageously adopted on the St. Germains Railway, at the point where this line branches into the Versailles (right bank), in order to enable the trains to pass along rapidly from one line to the other. The switch rails being made equal to 9 metres (29 feet, 6 inches) in length, the deviation in this case is rendered very gentle. There is still room for the introduction of some other contrivance, under similar circumstances, to answer the same end, without exposing the passengers to a like danger.

Switch rails of the first kind are the only ones applicable where three or more distinct lines terminate in a single way. Several ways are often united in one by this method in Belgium. The plan has some advantages, which we shall allude to hereafter; it should, however, be avoided as much as possible, especially on lines intended for the conveyance of passengers.

Changing places of the *third kind* are the oldest in use. This plan had been abandoned on the permanent way, on account of the effect produced upon one of the switch rails, by the engines and wagons pressing laterally against it; and from the rapidity of the motion in passing along from the oblique line, whereby the rails got curved and were rendered unfit for use.

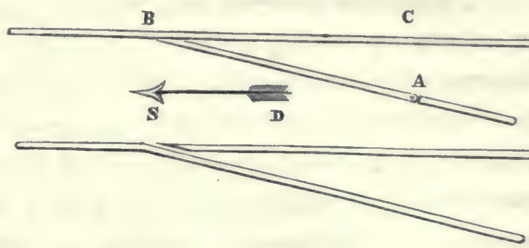
It has, however, been preferred recently to the check-rail on some important railways, as those of Rouen and Orleans, but greater strength is given to the switch of the oblique line, and it is supported for a long distance against the rail and sustained by brackets.

This switch presents the greatest simplicity in its construction, and is not dangerous like those of the first kind, and alone possesses the property, when correctly disposed, of being worked by the train itself; without the help of a switchman in certain particular cases. (See the switch shown in Plate 11, and the description.)

Notwithstanding the advantages which this kind of changing place appears to offer, it is still open to improvements.

When the plan shown in Plate 11 is employed, with one moveable switch rail, the counterpoise causes the switch-rail to press against the rail of the leading line, so that the oblique line is constantly open. The trains always pass in one direction on a line formed with two lines of rails, and the changing places ought to be placed in such a manner, that the opening of the acute angle at A B C,

(See cut,) and formed by the intersection of the switch with the rail, should be opposed to, or point in the direction, D S.



The flanges of the wheels pass through the angle A B C, forcing the switch asunder in the passage, and the counterpoise brings it back again into its original position immediately after the train has proceeded. But if any derangement of the apparatus should occur, or an obstacle arise at the side of the switch, either from accident or design, so as to prevent its free motion, the train would be likely to get off the rails. It is, therefore, necessary, if the directors are unwilling to employ a man for the especial purpose of working it, that the overseers should be assured of its being in proper working condition. We have also to remark that the engines do not constantly proceed in the same direction, or along the same line at the stations, like the trains; it therefore becomes indispensable to work the switch by the hand in passing in the opposite direction, or that of S—D to D—S. The stoker certainly might get off the tender and perform this operation.

The point rail of the switch shown in Plate 11, alters its position much sooner than the switch rail, when the distance from the adjoining rail gets too great, by which the wheels fall upon the ballasting. In order to rectify this, the point is replaced on the Orleans and Rouen Railways by a second moveable switch-rail, which resists better. It shoulders against the rail in use for the straight line, without leaving any gap between them. The counterpoise in this case no longer keeps the oblique way open. The trains pass along the straight line without it being requisite for the wheels to displace the switches, and since they necessarily pass along one or the other switch, we fear that the action of the wheels, and their great weight, will soon twist and render them ricketty. The points of these switches may also become crooked, by which the engines proceeding in the direction S—D may be thrown out of the line.

A changing place furnished with one switch will keep the principal line open as well as another formed with two, but the working of the oblique way in that case can only be accomplished by displacing the switch.

We shall now terminate our exposition of the general advantages and disadvantages of the different kinds of changing places, and will proceed to examine in

detail some of those employed on the various railways, commencing with the sidings intended for temporary works.

A system of switches and crossings, consisting of square bars of iron screwed on to wooden beams, as shown in Plate 42, is often employed in England for the execution of earthworks. The curves of this changing place, as drawn upon the Plate, are too short for the passage of engines or even wagons proceeding at great speed, and are only applicable on lines where the traffic is carried on exclusively by horses, and it would even then be as well to increase the curve of the guard-rails at the crossing, in order to derive the greatest advantage from them, and the piece of wood which is employed should be protected by a plate of iron placed upon its face.

Other changing places are employed, as that shown in Plate 40, which was adopted on the St. Germains Railway, and which we have ourselves employed on the line of the Versailles (left bank), as well as the preceding plan, but the last gave us the greatest satisfaction. The passage of the wagons is very gentle when they are properly laid out. They are also simple in construction and perfectly solid.

It, moreover, presents another advantage, which is not unimportant in this description of apparatus—viz., that each of the switch-rails and crossings are of such lengths that the rails of the principal way do not require to be cut in order to be laid down. This is accomplished by making the switch of the principal way, including the heel, equal in length to the rail of the way of deviation, *plus* the difference requisite to compensate for the obliquity; and lastly, to make the crossing of the same length as the switch of the principal way. The head of the switch in these changing places undergoes great wear and tear, and therefore ought to be securely fixed by very strong bolts. It is also unnecessary to make the point so *sharp* at the crossing as indicated in the Plate, and the guard rails should be curved, to bring them more readily to the fixed points. The best mode of constructing the crossing rails consists of composing them of two pieces of wood, separated by a vertical joint, and secured together by bolts.

Lastly, it would be advantageous to reduce the length of the changing place by tracing the line of deviation with a double curve, by which it would be rendered more gentle, instead of carrying it in a straight line, as shown in the Plate.

Changing places have been used on some lines on which the switches are fixed upon cast-iron plates, and the fixed parts raised upon the same. The crossings are formed of single pieces of cast-iron. (See Plate 41.)

Changing places of this description require to branch off very suddenly, unless the plates are formed of very large dimensions, which would render the expense too great. They should, therefore, like those first described, be only employed in cases where the traction is performed by horses. They are frequently used in the interior of mines, and in the vicinities of the shafts, being of very simple construction.

The earthworks were executed on the Great Western Railway with what are called *American rails;* and changing places, after the plan shown in Plate 41, were employed even at those parts traversed by locomotives. This arrangement requires no specific *material*, and is extremely simple. It appears to us in every respect deserving of the greatest praise.

We will now turn to the changing places employed on the permanent way. We will first examine the different systems of switch-rails, according to the order in which we originally classified them. The crossing places being perfectly independent of the switches, and since the whole of them are applicable with any arrangement of the former, we will treat of them, and also of the various contrivances for working the switches separately.

The switches employed in the changing places, furnished with moveable rails (*the first kind*), were originally formed of a single line of rails, or square bars of iron. (See Section C—D and Plan, Plate 20); but it was soon found that this plan did not possess sufficient solidity to resist the lateral pressure of the trains passing into the oblique way, and that the heel-bolts which secured the switches were displaced by the pressure of the wheels in passing over them. These defects were remedied by substituting double switch-rails instead of single ones, as represented in Plate 13. The bolts on which the switches turn are placed at the other end in this plan, next the two branch lines, and between the double rails, forming each switch. The wheels are therefore no longer able to touch it, the head of the switch being formed by cast iron chairs to which the double rails are screwed, which makes the whole much more solid. The switch itself also possesses greater strength; and as one of the two rails constituting each switch serves for the straight portion of the road, and the other for the oblique way, the latter is slightly curved in, which renders the deviation more gentle than changing places furnished with the single switch.

It is not merely necessary in this kind of changing-place that the double rails, forming one switch, should be joined together; the switches themselves, (i. e. each double switch) must be united in such a manner that flection in any direction shall be impossible.

We perceive, by an inspection of the Plate (13), that the sleepers which support the switches, are not connected, which is a defect in the apparatus that ought to be remedied. It would be preferable to form a long framing of very strong timbers, and of a fixed shape.

Plate 14 represents a description of switch, with moveable rails, employed in Belgium. It is formed of square bars of iron, fixed to an iron plate, which gives it greater power of resistance in a transverse direction, and was formerly the only one suitable for a three-branch line.

The employment of these *three-throw switches* possesses the advantage of diminishing the number of branches, of rendering the operations more simple, and of reducing the ground occupied by siding places at the stations, considerably. They are, however, the most liable of any to expose the trains to the risk of getting off the rails, as we have already pointed out. These switches have been used in the construction of the earthworks on the line from Lille to the Belgian frontier.

We recommend the number of sleepers always to be increased when they are used to support the switch-points, as shown in the plan.

In changing places furnished with the *check-rail* switches, the carriages adhere by the flanges of the wheels in a groove situated between the switch and the adjacent rail, by which method the switch directs the train.

By referring to the plan of the set of switches shown at Plate 16, we may observe that a train coming from the direction A A′, would pass along the rails S S′, since the flange of the right wheel being confined between the switch D and the rail S′, the left wheel is consequently obliged to pass over to the rail S. It may be further perceived that the space between the rail S′ and the point of the rail S, ought to be made equal to the distance between the flanges of the wheels, and that the greatest precision is necessary in constructing this part of the way.

We have stated that this crossing possesses the great advantage over the other, of not throwing the trains off the line, when the switches may chance to be improperly set, except in certain cases, which are extremely rare. Supposing the switches were in the position shown in the "Plan of the Switch," (Plate 16), and a train was coming by the line R R′; the right wheel, meeting with no obstacle, would pursue its path, while the left would meet the end of the switch at *g;* but since this part is formed sloping, the flange would consequently ascend the slope, or inclined plane; by which the carriage would run along the top of the switch,

and then drop down between the same and the rail at A, which would cause a slight shock only to the passengers.

In case of a train proceeding from the oblique line, and travelling at great speed, meeting with a switch placed falsely; then, supposing the two ways are curved, it might be thrown off of the line at the moment of passing on to this switch, from the action of the centrifugal force, arising from the velocity, preventing the flange of the other wheel catching in the space left between the switch and the rail, the direction of which is oblique to its movement.

Thus we see, that when the changing places are placed so that the junction of the deviation with the principal line is made in the direction of the course of the trains, and carried in a straight line, no danger can arise, even when the trains are proceeding with great speed. It therefore becomes necessary to avoid, as much as possible, placing the changing places at the curves.

We have frequently seen an entire train pass along switches badly placed, without the least accident occurring, or scarce a trace of the passage to be perceived on the switches.

The switches ought to be constructed of great strength, in order to be able to resist the pressure and the shocks when the engines and wagons are passing over them. When they are properly laid down, not only are the passengers free from danger, but the switches perfectly secure from getting displaced.

We have pointed out the necessity for the deviation being made sudden, as one of the defects of a changing place constructed with *check-rails*, since a train following the line A A′, Plate 16, and taking the way R R′, ought, in fact, to deviate in a lateral direction along half the switch, to an extent almost equal to that which separates the interior edge of the rail S′ from the point R′, in order that the flange of the right wheel which runs along the inside of the rail S′ shall follow that of the rail R′. As the wheel is liable, during this lateral movement, to fall between the rails, we must not fail to leave the proper space between the rail and the point of the fixed rail, and to maintain the same by solid frame-work. It is, of course, necessary to make the peripheries of the wheels of sufficient width.

There is another circumstance, also, to be taken into consideration in the construction of check-rails. When the trains pass into the oblique way, one of the switches is pressed, laterally, with great force by the wheels, and should it become displaced, the point of the rail S would get out of level, and as the wheel encountered this projection, it might rise on the rail, and derange some part of the apparatus, or even get off the rails. The liability of such an accident may be

rectified, first, by joining the switches carefully to the moving rods, or with the connecting rod of the eccentric, as well as the connecting rod with the eccentric; secondly, by placing the point of attachment of the switch nearer to its extremity; thirdly, and lastly, by regulating the eccentric in such a manner that it shall be necessary to force it a little after the switch is brought in contact with the rail. It is customary to make the distance from the eccentric to the point K a little greater than is actually shown in the Plate, to ensure this result.

To conclude: as the switch D′ supplies every effort requisite for the deviation, while the switch D merely serves to support the natural tendency of the train to follow the direct line, it is advisable to place the eccentric as near as possible to the side of the switch D′ which then acts more directly upon it, and the shaft partakes of the force of the traction.

The first changing places constructed in England after this system, were executed with very short switches, formed of slight section, the deviation being very sudden. The length of these switches is increased greatly in France, on the St. Germains line, and additional strength given to them; and the dimensions represented in Plate 20 have been at length adopted, which are considered quite sufficient.

The switches on the Versailles Railway (left bank) are formed with projecting edges, and those of the railway from Strasbourg to Basle, of flat bars; both of which systems are equally good.

The switches employed on the changing places of the Versailles Railway (left bank) are fixed on very solid framings, resting on timber beams, faced at certain intervals with small iron plates, upon which the switches slide, which plan has been found to answer very well.

This method of sustaining the switches allows of a wheel which may have fallen between the switch and the rail in consequence of a displacement of the apparatus, to run on its edge and ascend the fixed point readily, and so continue its course. It is more simple and convenient to rest the switch on a shoulder placed on one side of the chairs, as on the line from Strasbourg to Basle. (See Plate 15.)

In laying out a crossing on the model of that of the Versailles line (left bank) it would be advantageous to increase the length of the switch D′, between the joints of the rails A and R, beyond that shown in the Plate, and to replace the angle at that part by a curve; it would also be necessary to give a greater curve to the heads of the switches towards the inside of the way, which would enable them to force the flanges of the wheels to catch in the groove better.

The switches on the railway from Strasbourg to Basle operate very well; we

think, however, that it would have been preferable to have fixed the chairs, which support the heads of the switches, to the sleeper with bolts, independent of that forming the axis of rotation of the switches. This has been done on the Versailles line (left bank). We think, also, that it would have been as well to have secured greater solidity between the sleepers, by means of longitudinal timbers, or in the arrangement of the switches, more especially of that which supports the eccentric.

The Fixed Points of changing places formed with check-rails, are composed of rails with the upper champignon removed on each side, which operation ought to be performed when the iron is cold, and it is best accomplished with a planing machine. These pieces ought to be of iron of good quality and carefully worked, as they are soon worn away and partially destroyed by the passage of the trains.

We have only given one representation of a changing place of the third kind, with counter weights, which is used in England on the London and Birmingham line, being worked with one switch.

The crossings of the ways, as well as the switches, ought to be studied and laid out carefully. It is necessary to make the distance between the point *i*, in "Plan of Crossing Place for two lines," Versailles (left bank), Plate 17, and the guard-rails, R′ and R″, as little as possible, first, in order that the peripheries of the wheels supported on R′ and R″ should not undergo any shock previous to leaving the point *i*; and secondly, that the point should not be compelled to support the whole weight of the wheels, since it is of slight section and would be speedily destroyed.

It is necessary that the angle of the crossing should not be more acute than is requisite, which is another reason for laying out the changing places with a double curve. The point ought to be at least 15^{mm} (0·59 inch) thick at its extremity, in order to preserve its shape.

Guard rails should be laid down upon all the crossings of the way, by the side of those rails which are not interfered with, since, by guiding the flange of one of the wheels, they force the train to continue along the line to which the switch has directed it. If this precaution is not taken, the wheels passing over the crossing in the direction C A, might take the direction A D or A D′, when the other wheel would fall off the rail.

The fixed parts of the changing places, which are called *crossings*, are formed of cast-iron in Belgium, and form one piece, together with the plate supporting them.

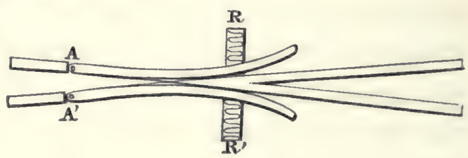
This system is very simple and economical, although the crossings are necessarily very short, and are subject to be broken and crushed under the

pressure of the wheels. The use of this description of crossing is discontinued on every other railway.

On the line from Strasbourg to Basle, crossings formed of one piece of wood have been used, on which square bars of iron were secured with screws and bolts. We have already stated the great inconveniences which rails of this description present in treating of the laying down of the way upon constructive works.

On the Versailles (left bank), and most other railways, the crossings of the way are composed of rails fixed in chairs of particular shape, with wedges of the same kind as those employed on the other parts of the line. This system, although the most expensive, is incontestably the most convenient. It is very firm, and does not present a difference in the mode of constructing the way like the others, which produce unequal settlements after a short time, and give rise to shocks during the passage of the trains.

The following description of crossings have been used on some English lines, more especially on the Newcastle and Carlisle Railway:—



The point is fixed, and the two parts forming the guard-rails are moveable at A and A′, and are constantly pressed against the fixed point by spiral springs, R and R′, or by counterpoises. Upon the passage of a train, the flanges of the wheels easily throw open the guard-rails which stand in their way. Therefore there is no suspension in the continuity of the rail which the wheels run on.

Shocks are not, however, often felt with fixed crossings if they are well laid, and the tires of the wheels formed of sufficient width. There is, therefore, no occasion to replace these by machinery, which is much less firm, more complicated, and dangerous; for if the action of the moveable rails should by any cause become obstructed or stopped, the flange of the wheel passes on them, or strains the apparatus.

The rods moving the switches are put in motion after different plans, as by levers, by cranked shafts, or by eccentrics.

The lever has been exclusively employed for some time past in earthworks. It is difficult to fix it so that the pressure of the flanges of the wheels against the switches should not cause it to change its position, while the cranked axle and the eccentric, being placed at the *dead point*, have not this tendency to get deranged.

The switch represented in Plate 11 is sometimes used with a counterpoise

added to it, which is shown at N in the plate (Details of Lever), the use of which is explained at pages 102 and 103.

The cranked shaft used for moving the switches was placed in a vertical position originally, and furnished with a handle, which system has been adopted on some of the changing places on the Belgian lines, and for the Paris and Versailles Railways (right and left banks).

A horizontal cranked axle is used on the St. Germains line, with a lever fitted to it, which makes a half revolution. See N, E, and P, Plate 20. This method is found inconvenient for the workmen, as it obliges them to stoop to the ground, and does not permit the signals being placed up above them to direct trains at a distance, and to show whether the line they are running on is open or closed. This lever, further, does not effect much saving, compared with others. The lever used on the Versailles line (left bank) acts very well, and is of a convenient size, but it is difficult to attach a signal firmly to it.

The apparatus shown on Plate 13 was originally used instead of the lever, on the London and Birmingham Railway. It consisted of a cast-iron box, containing an eccentric, with a moveable spindle attached to it. The latter was supported on a chair by four iron standards, which rested on the box, and guided the spindle. This contrivance having been found expensive in the adjustment, and as it presented several fastenings, which sometimes became ricketty, a cast-iron column has since been substituted, as shown upon the same Plate, which is more firm, less expensive, and much superior in appearance. The run of the switch being double that of the eccentric, the latter is consequently at the dead points at the time that the lateral pressure of the train is exerted, which tends to displace the switch; it is therefore necessary to fix the lever by a pin, or by some other means, by passing the dead point of the eccentric a little further, in order that if any effort takes place, it should be exerted upon a fixed point.

Details of an eccentric employed on the Liverpool and Manchester Railway are given in Plate 16. It is similar to the others, excepting that it is not inclosed in a cage.

The eccentrics used upon the English Railways are made of cast iron, and fixed on shafts, which renders it necessary to form them of very large diameters, and consequently to employ very large collars and cast iron boxes.

The eccentrics on the line from Strasbourg to Basle are made of the same piece as the shaft, so that its diameter is reduced to a minimum. The collar consists of an iron ring, which is turned so as to be easily adjusted, and without much expense; by which the size of the iron box is reduced considerably. It is

necessary to leave an opening for the passage of the rod, such as is left when a cranked shaft is employed, which is not the case with the English apparatus.

As an eccentric costs no more than a cranked axle, we see no reason why it should not be preferred.

All the eccentrics employed on the line from Strasbourg to Basle are moved by a double lever, which the workman stops by means of two spring latches, by laying hold of the handle. The use of latches affords greater security than pins, and saves time in the working.

The lower part of shafts having handles or eccentrics such as we have just described, are always placed in cast iron boxes. It is important that these boxes should be perfectly close, so that the sand raised by the wind should not introduce itself between the parts which rub together.

We have said that it is necessary to place the signals on the shafts of the eccentrics. They generally use a disc painted two colours, which shows the direction in which the switches are turned. But since it rarely happens that all the branching-off places on a great line are placed in the same direction, it follows that an engine driver is obliged to look out for some eccentrics of one colour, and others of another, in order to be sure that the way is clear; and if the movements are very much varied, his memory may fail, whereby he may be betrayed to make erroneous movements.

The discs are replaced at night by lanterns also of two colours; but since the switches themselves can no longer be seen, and since, moreover, the engine men cannot always judge accurately of the distances and positions of the several luminous points at a station, the difficulty is much greater than in the daytime. We think that the following signals are better:—

A flame of plate-iron, painted of a very vivid colour during the day, which will show, by the direction in which it is turned, the position of the switches, and a triangular lamp at night, of which the luminous part forms a point, which furnishes the same information.

The plans of the different changing places are shown complete in Plates 14, 16, and 17. The length of changing places, especially those constructed with moveable rails, varies greatly. A changing-place, formed with check-rail switches, for a gauge of 1^{m} 50 (4 feet 11 inches) and an interspace between the lines of 1^{m} 80 (6 feet), would require a length of between 50 and 60 metres (55 yards and 66 yards.)

We have stated that the position of the changing places, in one direction or the other, on those parts of the line where the trains pass at great speed, is not a matter of indifference. The trains pass along the (upper) line next the margin

of the plate, from left to right, in the general plan of change of way (Plate 17); and on the other line from right to left. The switch employed being of the first kind of the previous classification. It is necessary that this changing-place should be arranged as shown upon the plan. If the switch should be placed wrong during the passage of a train, the latter would merely run along the branch, instead of the straight line, but this would not be the case if the train was passing in the opposite direction. If it passed on the branch at great speed, it would either strain the switch or get off the line, on account of the small radius of the curve in the siding-place; or lastly, meet the switch placed properly on the principal way at the other end of the deviation, and then run off the rails. But even admitting the last supposition, which is the most unfavourable, the train would not get off until its speed becomes considerably diminished from passing along the siding. The accident would therefore be much less serious than if the train had got off the road, and been driven at full speed in a straight direction.

Changing places formed with check-rails ought to be placed in an opposite direction, or, what is the same thing, the trains should be arranged to proceed in the opposite direction to that which they follow in the last case (see Plate 17); *that is to say*, from left to right along the (lower) line next the margin of the plate, and from right to left on the other, the changing place being fixed in the same direction as that shown in Plate 17. The trains are then never exposed to follow the branch, and if the switches are badly placed they pass over them without losing their straight course.

We will now examine a changing place entirely different from those commonly employed, and which was constructed to enable the trains to pass along at great velocity. It is placed on the St. Germains Railway, at the Asnieres Junction, where the Versailles Railway (right bank) branches off. The portion used by both lines extending from Paris to Asnieres, is made equal to a length of 6 kilometres (3¾ miles), and is furnished with three sets of rails. The trains from St. Germains take the left rail, those from Versailles the right, so that the intersection of the Versailles is made to the left of the departure line, which is the middle one, and common to both railways. The crossing of which we speak is formed at the branching off of the middle way, and represented in Plate 19. It is 63 metres (69 yards) long from the head of the switch to the point of the crossing, which is nearly three times that of ordinary changing places. It is very gentle in passing over, even with trains travelling with great velocity.

The lines being too oblique for such a great length, it was necessary to make the crossing moveable as well as the switch-rails, and the same shaft is employed

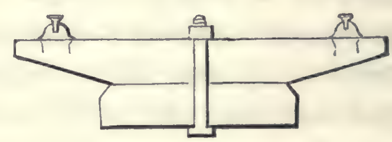
to move each. The plans represent the change of way, disposed so that trains shall pass along the right hand line, or the St. Germains line. This apparatus acts in a very satisfactory manner, and the working of it is explained in the description of the Plate.

SECT. II.—*Of Turn-Tables.*

There are two methods of turning or changing the direction of trains, or of the carriages separately on railways. The first consists in causing them to describe a curve; the second, which is only applicable to the carriages separately at the stations, consists of making a part of the line moveable, and placing the carriage or engine on this moveable portion, upon which it is turned to the angle required.

The moveable part of the way in this case takes the name of *turn-table*, or *turn-plate*.

The following apparatus, which is used for earthworks, is comprised under the head of turn-tables, and may be described as the simplest of all, being constructed of two sleepers, placed one upon the other, and united by a bolt, as shown in the cut.



The upper sleeper carries two chairs, or one at each end, and two portions of rail are fastened in the same at about the middle.

This kind of turn-table is not only employed for earthworks, but is extremely useful at the early stages of a railway, when large quantities of ballasting require to be moved, for the maintenance of the way. The wagons, by the means we are about to explain, may be placed on the line during the evening, when work has to be performed at the night, and removed to the sheds, either by the side or outside of the railway station in the morning, without interrupting the way by crossings or fixed turn-tables, which are expensive, and may also occasion accidents.

When this apparatus is employed for earthworks, the moveable rails form a part of the way. The upper sleeper is turned on its pivot, in order to change the direction, and a railway sleeper is then placed before each way, upon which the ends of the rails rest, by which the movement is facilitated. The moveable pieces are united by a bolt passing through them, which gives the requisite firmness to the plan. When this turn-table is employed to place the ballast-wagons

on the permanent way, the lower sleeper is placed so that the rails of the turn-table shall be above those of the line, and the shed for receiving the wagons is placed at the same height as the rails on the turn-table. Wooden wedges are made use of to enable the wagon to pass on to the principal way or to take it off, which equalizes the difference of level. The operation is very easy, since the wagons are always empty when they are placed on the moveable rails.

The wagons being conveyed to the line or to the station, the upper sleeper, with its rails, is then raised, and there no longer exists any obstacle to the passage of the trains.

A provisionary station is built on the line from Strasbourg to Bâsle, for the loading of coal, and the turn-tables are formed after this plan. The wagons weigh 2500 kilogrammes (5112 lbs.), and carry 4000 kilogrammes (8820 lbs.) of coal. Skilful workmen can turn wagons on these platforms with great facility, and as quickly as on the ordinary ones, and no accident has occurred during the many months that they have been used at that station.

The platforms, or turn-tables, *properly speaking*, erected permanently on the way, are composed of three distinct parts.

1st. The *frame* of the table, which supports the ends of the rails.

2nd. The *pivot*, on which the centre of the table is placed, and the rollers supporting the circumference.

3rd. The *well-hole*, or trench, below the table on which the pivot and rollers are placed.

The frame of the turn-table is either of cast-iron or of wood. Those formed of wood cost less on their first establishment than the former, but they require more superintendence, and are not so easily worked. We think that there should be no hesitation in the adoption of cast-iron turn-tables on all lines of any importance, and they are decidedly to be preferred for locomotives, whatever the cost may be. One of us having used timber turn-tables, has discovered all their inconveniences. They are, however, still employed in the north of England, on the line from Vienna to Brun, and on many other railways.

Turn-tables carry one set of rails only, or two arranged crossways: the first, when not properly placed, are liable to interrupt the traffic and prove dangerous.

The construction of the pivots offer little variety; we shall review the different descriptions of pivots in describing the turn-table represented in the collection of Plates.

The rollers are either fixed or moveable; the fixed rollers turn on their axles. The moveable rollers revolve between two circular iron plates, the upper one

being fixed in the frame-work of the table, and the other laid at the bottom of the trench.

The friction with the fixed rollers consists of a sort of *grating* upon the axis of the rollers, together with the rolling friction. The friction at the circumference is all that occurs in the motion of moveable rollers, whereby the latter are generally preferred at the present time.

The moveable rollers are kept at uniform distances from the centre of the table by their axes, which are prolonged in the direction of the radii of the circle in which they revolve, and are then fixed in a collar, through which the pivot passes. Their axes are also united together by two circles of iron, which thereby preserve the proper distances. The rollers of the turn-tables employed in England are generally placed at the extreme circumference of the table, but the engineers of some of the railways in France have endeavoured to bring the rollers nearer the centre, for the purpose of reducing the expense, and to render the movements easier, which has had the effect of diminishing the stability of the platform. It was found that the passage of the trains soon shook their foundations. The small saving effected by the use of these turn-tables does not appear to us to compensate for their defects, more especially where the rollers are very near the centre, for instance, as the original turnplate of the Orleans Railway.

Turn-tables are never employed except at the extremities of the stations.

The peripheries of the rollers are sometimes rounded, in order to avoid turning them, as well as the bands of iron upon which they roll. When the moveable rollers are formed with rounded peripheries, they require continual repair, and render the working very difficult, since they never preserve the position intended. This is not the case when they are fixed, the weight which they support preventing their getting displaced so easily.

The foundation requisite for turn-tables is regulated by the nature of the ground; they should be built on piles (see Plate 30), or on circular walls of masonry (see Plate 33), if the soil is not firm, and whenever they occur on embankments.

Timber foundations are more elastic than those constructed of stone, by which they ease the shocks which the platform is subject to receive when the engine is being passed on the turn-table; but as they suffer from the action of the water falling from the locomotives during their passage, stone foundations are therefore preferred. It may be further remarked, that whatever kind of foundation is adopted, the construction of drains to lead off the water must not be neglected.

The vertical lining of the well-hole should consist either of walls of cut stone, of cast-iron circles, or of walls formed with small stones, and crowned by wooden curb plates. The shocks arising from the passage of the engines, together with those produced by the stops or bolts, soon unsettle the masonry and the pins of the chairs.

We were perfectly satisfied with the wooden curbs which we employed on the Versailles line (left bank), and consider them far preferable to any others.

The turn-tables used on the St. Germains line are copied from those formerly employed in England.

The rails are cast in one piece, with the framework, and, being too slight, they soon wear out, more especially those parts which form the passages for the flanges of the wheels. The shocks which they receive soon disorganize them, and upon these rails being worn out, the turn-plate becomes useless.

We must condemn the fixed rollers equally with the last, and for the same reasons, the cast-iron covering being so liable to break, from the shocks of the engine getting off the rails, or any other cause. The foundations being of cast-iron, also renders their expense very great in France, where this metal is still sold at a high price.

The mode of constructing the turn-tables on the London and Birmingham Railway, represented by Plate 27, is more satisfactory. The rails, which are made of wrought-iron, are directly sustained by strong ties, and fixed firmly to the table by means of bolts.

The grating, covering the framework, is made of cast-iron, also the foundations.

The rollers are moveable in each of the models represented in the Plate, but they are made of the rounded form in the smaller turn-table, which we do not approve of. The frame of the table is suspended on the pivot by four bolts, as shown by the sections, and the weight which the pivot and rollers are required to support is regulated by the same.

This arrangement is excellent, and has been adopted with almost all the turn-tables recently constructed; not only does it render the working easier, but also prevents their breaking when subjected to false equilibrium at the time of the locomotives passing over.

The turn-tables formerly employed upon the Versailles Railway (right and left banks), had their rollers placed much nearer the centres than the top, the defects of which mode of construction we have already exposed. The foundation of rollers thus constructed costs the same as those having their rollers arranged

around the circumference, and the saving effected in the whole apparatus is of very trifling importance.

It is further impossible to continue this mode of construction when the turn-tables are disposed for a double way, since the iron rails, which are prolonged with a false support beyond the circle of the rollers, will not admit of being cut to allow of the passage of the flanges of the wheels without losing all their stability. It is also necessary to state another inconvenience attending the turn-tables we are speaking of, which consists in the difficulty that is found in fixing them firmly to the planks and bolts to keep them in their position.

The pivot of these turn-tables appears deserving of imitation, being inverted, by which the water and ashes are prevented falling into the sockets. The weight of the platform is regulated the same as the preceding ones.

We will remark, lastly, that the piece of cast-iron employed to fix the pivot to the stone at the foundation, is of a shape which renders the connexion difficult to accomplish, since it is not easy to introduce the solder required between the iron and the stone, so that the fastenings frequently get shaken, and require repairing.

The circle on which the rollers run is cast in one piece, and fixed directly on blocks of cut stone, fastened by cramps to the body of the masonry. It is turned in the same manner as the upper one, which is fixed to the table and the rollers themselves.

The rollers of the original turn-tables on the Orleans line were brought still nearer to the centres than those on the Versailles. The false bearings were so much extended that a simple fastening was not sufficient to sustain the pivot. It was therefore placed in a socket, which was formed in the shape of a disc of large diameter, upon which the rollers were fixed.

The rails upon the turn-table were cast with the same, and the weight on the pivot was regulated by the key, which appears to us a more complicated plan than bolts placed within reach of the workmen. These turn-tables have been lately replaced by others, greatly resembling those with moveable rollers on the London and Birmingham Railway.

The turn-tables on the Great Western Railway (see Plate 29) appear to maintain their proper positions. The great width of this road allows of the adoption of a very convenient mode of supporting the points of junction, and the space between each pair of rails. The ways are then well sustained, and the distribution of the metal is very regular.

The pivot is cast in one piece with the foot-plate, and fixed to the masonry

by bolts, which mode of fastening is both strong and easily executed. The turn-tables are covered by strong oaken planks, upon which the rails are fixed. This disposition is, in our opinion, very serviceable, as it softens the shocks which the rails receive, both when the engines pass from the road to the platform, or in passing over the joints, and prevents reaction, which is injurious to the different parts of the table and fastenings. The cast-iron curbing of the masonry inclosing the top of the turn-table will, in our opinion, be soon shook out of place, from the effects of the latchet stop connected with it. We should prefer the use of wood curbing.

The iron does not appear to us judiciously distributed in the turn-table used on the Gard Railway, although copied from an English model; and the arms of the table are often subjected to fracture at their extremities nearest the centre.

The cast-iron turn-tables of the Liverpool and Manchester Railway are much better distributed, but it was found necessary to diminish the relative size of the several parts, in order to avoid rendering them of too great weight, which reduced their strength, and was doubtless the cause of this model being abandoned.

The turn-table on the railway from Strasbourg to Bâsle (see Plate 35), like that of the Great Western, is covered with a flooring formed of planks, on which the rails are laid. The crown plate supporting the rollers is of wrought iron, fixed on a wooden frame. The rollers are generally rounded at their peripheries, but are not turned, nor the circles on which they roll, whereby the tables are rendered very difficult to work. The iron circles, possessing only a slight power of resistance, become curved, and the rollers, although sustained by very strong rods, frequently get disarranged. It has been found necessary, in some instances, to add a second circle to the turn-plates to keep them in order, but this has not remedied the defects. The turn-table represented in the Plate (35), is intended for the locomotives.

The turn-tables, which are placed in such situations upon the line that the trains pass across them, are only used for shifting wagons, and constructed about three metres (9 feet 9 inches) in diameter; are of the same form as the last, but have wood interposed between the rails and the iron plate. These turn-tables, being exposed to great strains, are frequently subjected to fracture.

The curbs of the turn-tables on the line from Strasbourg to Bâsle, are formed both of stone and of wood. Those of wood are much the most serviceable, and are substituted in place of stone as fast as the latter gets worn out.

The Plates 30 and 33 represent the foundations requisite for turn-tables in

particular cases. The Plate 33 gives the details of the foundation of a turn-table placed in the centre of a circular shed. A circular drain is left in the body of the masonry, which receives the water from the platform, and all the drains leading to it. The plan shows a portion of the drains, and the crossings of the different lines connected with the turn-table.

The Plate 32 gives the details of a turn-table formed entirely of wood, and executed on the Versailles Railway (left bank), for the use of the wagons. The rollers are fixed to the upper part, and roll on an iron circle; the movement of this table is very gentle, as it is well supported. The fastening of the upper portions of the wooden crown pieces is accomplished in such a manner that the pieces L, L′, are dropped in from above, and form wedges, thereby serving to fix and strengthen all the fastenings together. The beams placed upon the rollers receive these pieces, and maintain them in their places.

Timber turn-tables have been employed on the line from Newcastle to Carlisle, not only for the carriages, but also for the engines. It is necessary in these cases that they should be carefully constructed, and very solid. It seldom happens, when these large dimensions are adopted, that the water running from the engines does not injure them.

Timber turn-tables have also been used in Austria, with moveable rollers; there is reason to believe that these are deficient in stability, being of comparatively weak construction.

SECT. III.—*Slide Rails for changing the Line.*

Turn-tables are not the only means employed to shift carriages and engines from one line to another. Parallel slides are also used to accomplish the same, which carry a pair of rails, and run on a railway perpendicular to the parallel lines to which it is applied. The slide is placed over a kind of trench, prepared on purpose, by which the surface of the rails fixed on it is made of the same level as the ways of the railway.

The carriage, or the engine required to be moved, is merely run out upon one of these slides, and taken where necessary. One slide will consequently serve for a great number of parallel ways abutting upon either side of the trench, and their cost is much less, both in the first expense and in the maintenance, than the turn-tables which they answer for. But since all the lines are interrupted by this plan, except that with which they are connected, it cannot be employed without some risk of danger; turn-tables are therefore generally preferred, on the principal

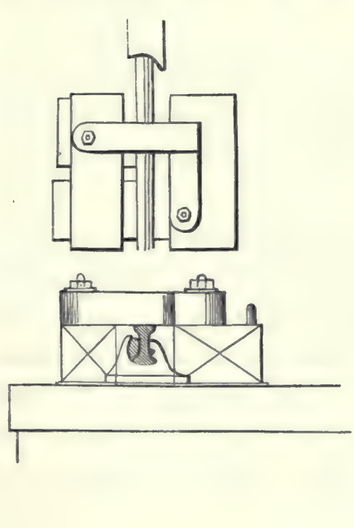
lines of a railway. The turn-tables, moreover, may be made to admit of a passage in any direction, while the slides will only allow of a parallel movement.

The rails of the slide are sometimes fixed to a wooden frame, which rests by means of the grease-boxes upon the axles of the slide, as the slides used in the engine-house on the Strasbourg and Bâsle Railway, and in the workshops of the St. Germains. The trench in this case is not required to be so deep, or more than the height of the axles, above the level of the rail line of the wheels, *plus* that of the grease-boxes above the axles, and the thickness of the frame; but the trench, even then, being dug in the centre of the building, becomes a serious impediment to business.

The depth of the trench is reduced on the Versailles Railway (left bank) to 20 centimetres (8 inches), (being the usual height of the step of a staircase,) by suspending the frame from the axle instead of placing the same upon it.

It is true, that the slide is only intended to shift wagons; it has, however, been applied to engines, and there is no reason why it should not be employed for *housing* them, by modifying some of the dimensions, without increasing the height much.

It sometimes happens, at the period of lighting the fires of the locomotives in the engine-house, that an escape occurs in the steam-pipe or entrance, which causes the engines to move, if they are not scotched by wedges; they might otherwise fall into the trench. Wedges which cannot be either displaced or removed, are securely fixed on the borders of the trench, in order to prevent this kind of accident. See the Cuts. These wedges are also employed on inclined planes, to keep the trains at the top.



If the carriages arrive by a line perpendicular to that of the sheds, or by lines in different directions, the slide we have just described is replaced by one carrying a moveable turntable.

This apparatus being rather complicated, does not possess sufficient stability to be employed for the engines. It is only used for carriages, and some difficulty is found in working it even with these light weights.

Sect. IV.—*Level Crossings and Fencing.*

Those portions of a railway which are crossed by roads formed on the same level as the railway are called *Level Crossings.*

The permanent fencing employed in France and England, to inclose the railways, is generally replaced by gates wherever a road crosses, and either the guard or another man is specially appointed to attend the same. The lines being seldom inclosed in Belgium, these gates are unnecessary. Guards are only occasionally employed on a few of the most frequented roads; it therefore becomes the duty of the public who cross the line to take care that there are no trains in sight at the time.

Serious accidents sometimes occur from defective fencing, or imperfections in the gates.

A cow once strayed on the Birmingham line, and was the cause of the train being turned off the rails, when several of the passengers were killed or severely injured; and a similar accident occurred on the Liverpool and Manchester Railway.

It appears, at first sight, dangerous for the public to pass over these crossings on the level often. We, however, think, that if the police regulations were less strict in France, and the authorities were not to insist upon these crossings being kept constantly closed, nor the public vexatiously restrained by *employés*, who are constantly induced to infringe their duties, and be deceived, less accidents would occur.

We do not pretend to deny that these crossings on a level do not present some danger, especially when the roads are much frequented and intersect the line of railway obliquely, when they cannot be seen at a distance by the engine-drivers.

A carter crossing over one of these passages on the Versailles Railway (left bank), unobserved by the guards, at night, the road being very oblique, lost the proper track, and was within an ace of meeting a train coming from Versailles at full speed. Another man, crossing the railway at a different point, in spite of the guard, at the time a train was expected, the engine-driver could scarcely arrest the train without a collision, as it was descending an incline. In short, we admit that the terrible catastrophe of the 8th of May is chiefly attributable to one of these level crossings.

It is therefore necessary for the public safety to avoid these level crossings

as much as possible, especially on the curves, in cuttings at the bottom of inclines, and on roads that cross the railway obliquely, or are much frequented.

Bridges may be substituted for crossings on the level, and the roads carried either over or under the railway. Bridges are more advantageous than gates as respects expense, and a saving is effected by adopting them. The interest of the capital required in their construction and repairs does not equal the annual expenditure required for a level crossing and its guards, with the interest of capital employed in the construction and the expense of maintaining the crossing and gates. The management of one of these gates costs 600 to 1000 francs (25*l.* to 41*l.* 13*s.*) per annum. The cost of constructing bridges and gates varies within very confined limits. The formation of bridges and of gates often necessitates the construction of approaches, which are very prejudicial in a flat country, or where the wagons travel heavily laden. The number of level crossings may be reduced by uniting several communications together. When a road passes over the railway by means of two approaches in opposite directions, the waters which descend from each of these roads under the bridge are sometimes difficult to carry off. We must not forget to provide means of drainage.

The construction of bridges is modified in various ways for the purpose of reducing the approaches on each side of the rails, and according to the height. We will merely remark, that it is possible for a railway to pass over by a bridge without inconvenience, like an ordinary road, by means of two opposite approaches; and if the gradient is slight, the engines can overcome it without much variation in their speed.

The number of these level crossings is much increased when the country is flat or the expenses are considerable. Thus we find a great number on the Belgian lines and on those of Alsace. There are 229 of these crossings within a distance of 134 kilometres (83¼ miles), on the line from Strasbourg to Bâsle. One guard is found sufficient to attend to several crossings. Although the ground is very hilly, on the Versailles line (left bank), the number of these passages on the level was increased, in order to reduce the absolute capital: there are as many as 23 on a length of 17 kilometres (10¾ miles). There is but one on the line of the right bank, which is at the Park of St. Cloud. Guard-rails are always placed along these level crossings, generally on each side the rails, but sometimes on the inside only (see Plate 37.)

These guard-rails are not laid down for the purpose of guiding the engines and preventing their getting off the rails, like those employed on changing places. When two are employed, they are always placed a little higher than the rails, so

that the carriages passing along the ordinary road, and requiring to cross the rails, pass over a kind of trough, at the bottom of which the rails are laid. The guard-rails on the level crossings also prevent pebbles or dung lodging on the rails. If guard-rails are only placed within, the carriages necessarily pass over the rails, and the former merely serve to protect the interior face of the rail, and to sustain the earth between the rails, in order to keep the passage free for the flanges of the wheels.

Although two guard-rails are certainly more advantageous than one, yet the latter plan is adopted on many railways from motives of economy, and without any injurious effects.

When crossings on the level are intended for the use of foot passengers only, guard-rails are dispensed with altogether.

The space between an inner guard rail and the rail, depends on the thickness of the flanges of the wheels of the engines or carriages, and on their usual distance (*more* or *less*) from the centre of the road. This space is generally 0.05^{m} (2 inches), on the Versailles line (left bank).

The iron guard-rails generally consist of the ends of rails, which are curved and fixed by chairs. (See Section of Single Guard-rail of Iron, Plate 37.)

If the section of the way between the guard-rails was formed convex, the water and mud would run in between the rail and the guard-rail; it is therefore generally made level. It is, however, impossible to prevent some dirt getting into these spaces. It should be constantly picked out and removed by the guards at the various barriers. This is more especially necessary in the winter, since the frost hardens it, whereby the engines may be thrown off the rails. The space between the inner guard-rails is filled with paving, pebbles, or planks. We recommend the adoption of the first, as it is the most durable, and does not require to be taken up when the sleepers are removed.

It is necessary to extend the paving at the crossing beyond that which is requisite for the gates, in order that the carriages should not fall between the rails, in the event of the horses taking fright or getting off the road, where they would be difficult to remove.

We remember a crossing which was obstructed in this way by a wagon at the moment the train was in sight, from being too confined.

The gates, or moveable inclosures, placed at the level crossings, are constructed in various styles, as represented by Plate 37. That of the Versailles (left bank) is one of the most convenient for the passage.

The gates are sustained by iron tie-bolts fastened to the upper extremities of strong posts, and the wooden frames forming the gates turn beneath the same.

The gates of the London and Birmingham are not sustained by bolts; therefore those of large size bend under their weight, or from the effects of people climbing upon them, and lose their proper shape.

The gates employed on many railways in Germany and Belgium are composed of simple beams sliding between the posts, as the "sliding-gate (*German*)."

These barriers are also used on the lines in Alsace, but they do not keep off the foot passengers effectually, and cattle of small size are able to get under the beams.

The iron gates employed to inclose the line from Strasbourg to Bâsle, where crossed by high roads (*route royale*) and important county roads (*route departementale*), are shown in the Plate. We think that simple wooden gates would have cost less, and have better suited the wooden paling inclosing the line.

The arrangement of the government engineers, of placing double iron gates with a pillar between them, appears to us more dangerous than useful. It is never necessary for two carriages to pass over at the same time, and the pillar placed in the middle of the gate is very objectionable at night, as it forces the carriages to take an oblique direction, whereby they are thrown off the road, as we have before shown.

The gates connected with level crossings generally open towards the railway, and sometimes in the opposite direction.

When the gates are opened towards the railway, they extend across the line, and carry a disc in front, generally painted red, which indicates to the enginemen at a distance that the railway is closed. Gates formed in this manner possess the advantage of preventing pedestrians and cattle, or even drivers, from getting on the rails on each side of the crossing. The gates are generally closed at night across the railway, and the guards stationed at them open the railway every time a train requires to pass; in the event of this being neglected, the gates, being left extended across the railway, are destroyed by the engines at work during the night, which are either engaged upon the maintenance of the road, or employed for the purposes of trade.

It may be stated, lastly, that gates cannot be used when the road cuts the railway at a very acute angle, as they would require to be made of such very large dimensions.

All the railways in France, with the exception of the Saint Stephen's and Lyons, are fenced in upon each side of the line, which protects the works. These inclosures are sometimes dispensed with, at the foot of large embankments, and the bottom of extensive cuttings, whose slopes are protected by ditches instead.

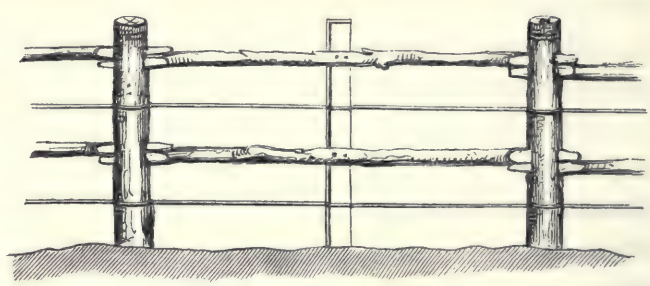
It is, however, very advantageous, as it prevents accidents from the passers-by leaping over the ditches, and slipping down by accident into the cuttings.

The fencing of many of the railways in the environs of Paris consists of simple trellis-work, formed of very slight laths of chestnut wood finished with points at their upper parts. A man cannot climb over this fence without breaking the laths, and it is found to protect the road very effectually, although only 1^m 13 (3 feet, 8 inches high,) when the cost does not exceed 1 franc, 30 cents, the lineal metre ($11\frac{3}{4}d.$ per yard.) (See the Documents.)

Pine-wood laths have been used for fencing on the line from Strasbourg to Bâsle, which is represented on Plate 37. It is not so good as the former, but is preferred in places where chestnut timber is scarce, and the workmen do not understand working the latter. It costs the same price as hurdles.

The fencing employed in England is much more simple and economical. It consists of rough wooden posts driven into the ground, in which two mortices are cut, which receive the ends of the rails.

These wooden posts are five or six metres, (16 feet, 5 inches, or 19 feet, 8 inches) apart, and there is a flat stake, called a *prick post* between them, on which the horizontal rails are nailed. The ends of the piles are sometimes bound with iron hooping, fastened by two rails, as shown in the cut. Iron wire is often stretched between the rails in the vicinity of towns and in pasture land, where animals of small size graze (see cut). Trellis work, formed of iron wire, galvanized, has been used in some parts of the Orleans line.



When the line crosses large estates, the trellis is replaced by high palings at double the cost, or by walls. Hedges serve equally well for inclosures in the place of trellis work.

Hedges are planted on a great number of railways within the original fencing, so that when the latter is worn out, it is replaced by the hedge, which requires less care and forms a better fence.

DOCUMENTS, ESTIMATES OF COST, AND MINUTES OF SPECIFICATION.

We have comprised under this title, Estimates and Specifications, together with observations on various subjects, which, although of great interest to practitioners, did not appear to require a place in the body of the work.

The estimates of cost (*prix de revient*) are not founded on theory alone, but are the results of practice, the perfect accuracy of which we have verified.

ESTIMATE OF THE COST OF EARTHWORKS EXECUTED BY MEANS OF RAILWAYS AND BY HORSES, ALSO BY LOCOMOTIVES.

We have already stated that we have not had an opportunity of studying the subject of forming earthwork by means of railways, and the employment of horses or of locomotives, with sufficient attention to warrant our attempting a description of the operation; but having executed some earthworks with wagons on the Versailles Railway (left bank) with a rapidity almost unprecedented, and which may be classed among the most important which has occurred in the construction of railways, we think that a statement of the expenses of the work will not be unacceptable to our readers.

The statement of prices, &c., exhibited in the following tables, is the work of Mons. Brabant, a very able and experienced superintendent of bridges and roads, and whose ability in the direction of these difficult works we cannot sufficiently commend.

We will, however, precede the tables by an explanation of the mode of operation adopted in the removal of the earth.

The tables of prices calculated by Mons. Brabant are only applicable, strictly speaking, to works executed under precisely similar circumstances to those in which we were placed; but it is easy to modify them, so as to make the same data applicable where the problem may be changed.

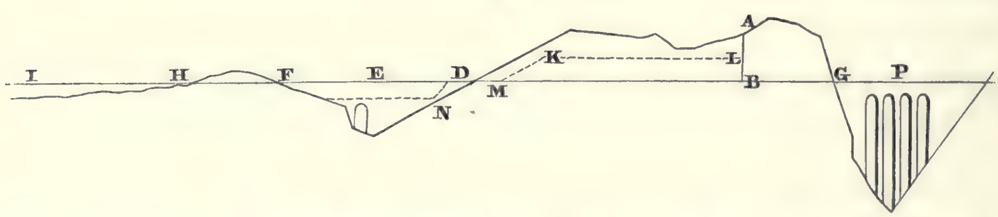
Of all the several railways now forming throughout Europe, none have re-

quired so great an amount of earthwork in their construction as that of the Versailles Railway (left bank).

The cubic contents of the earth removed from the single cutting of Clamart, crossing the hill which separates the valley of Clamart from the valley of Fleury, was 378,000 cubic metres (494,438 cubic yards), and upwards of three-fourths of this quantity required to be conveyed away from one extremity of the cutting —viz., that on the Paris side.

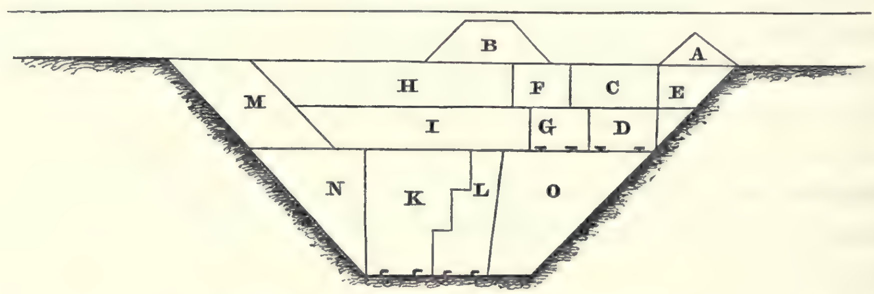
The directors of the line having instructed the engineers to employ the most expeditious methods, without regard to expense, in order that the line might be made available for traffic with as little delay as possible, they adopted a plan in which economy was sacrificed to extreme rapidity of execution.

Fig. 1.



Longitudinal Section of the Clamart Cutting.

Fig. 2.



Transverse Section of the Clamart Cutting.

Fig. 1 represents a longitudinal section of the earth along the axis of the cutting of Clamart, and the embankments in connexion with the two extremities of the cutting.

The earth to the left of the line A B was carried northwards, in a direction towards Paris, and that to the right, southwards towards Versailles. Of the 300,000 cubic metres (392,411 cubic yards) carried towards Paris, 120,000

cubic metres (156,964 cubic yards) were deposited in the valley of Clamart, for the embankment D E F; the remainder was used to form the embankments at H I, on the other side of the small cutting H F, called the *Vanvres cutting*, or was deposited in the valley of Clamart, in order to increase the embankment. The earth to the right of the line A B was carried to the embankment on the Versailles side, between the extremity of the cutting of Clamart and the Fleury viaduct.

The soil of the cutting was taken out in the following manner:—A small working cutting, or gullet, a longitudinal section of which is shown at K L A, Fig. 1, and a transverse section at D C, Fig. 2, was first opened on the northern extremity of the cutting, as far as the line A B, and large enough to contain a single way, and of various depths. The bottom of this gullet was formed at an uniform height of 7 metres (23 feet) above the intended level of the permanent cutting. It was formed with an inclination of 4 millimetres per metre (1 in 250) towards Paris, which was also intended for the inclination of the railway.

This small cutting, or gullet, having been commenced at a great many points at the same time, the earth arising from it was thrown up along the sides at A and B, Fig. 2. A pair of rails was next laid down upon the bottom, and earth wagons placed thereon, which were employed to carry away the earth of the mounds A and B, which could not be allowed to remain deposited on account of the great value of the land.

As soon as a part of the earth from the mound B had been carried away, the masses F and G, on the side of the first gullet, were dug out, by which they were enabled to lay down a second line of rails, the earth forming the mass E and that of the mass H being at the same time broken up and taken away by the wagons. A portion of the earth of this mass was conveyed by barrows directly into the wagons; another portion was conveyed to the edge only of the gullet, and thence cast into them by spades.

The mass of earth marked I, was transmitted entirely by spades,—one portion immediately after being broken down, and the remainder after having been transported by barrows to the edge of the way.

The remaining quantity of the lift forming this portion of the cutting having thus been excavated, the excavating of a second gullet, K L, was commenced, and from several points at once, as before, the greatest part of the earth being thrown up by casts of the spade upon the bank, and from thence transmitted to the wagons running along the railway in the upper gullet, or turned immediately into wagons run on a new line formed at the bottom of the gullet F G C D.

The mass L was next overthrown, and loaded directly into the same wagons,

and a second working line laid down in the cutting K L, and at length the rails laid along the upper gullet were taken up, and the masses N and O broken down and carried away by the wagons running on the lower gullet.

The soil consisted of beds of marl and lime, which were capable of supporting themselves, for some time at least, under very inclined faces. If they had been otherwise, the sides of the gullets could not have preserved the forms stated.

The earth was teamed or led along the temporary line laid for the upper gullet, by horses, and upon its arriving at the extremity of the same at K (see Fig. 1) was let down to the level of the top of the embankment by a self-acting plane (*plan auto-moteur*, see Plate 42), by which a loaded wagon, in descending, drew up an empty one.

The earth of the lower gullet was led to the embankment, either by horses or by locomotives, according to the distance.

The embankment was formed in two lifts, and the earth was let down to the level of the lower lift by means of two self-acting planes (*plans auto-moteurs*) projected at D N, and one of them corresponding to the line of the upper gullet, the other to that of the lower one. The earth of the upper gullet, forming a portion of the lower bed of the embankment, was thus let down by two successive self-acting planes (*plans auto-moteurs*), and that of the lower cutting by one only. The employment of locomotive engines for the conveyance of the earth of the lower cutting was not commenced until the *plans auto-moteurs* connected with the embankment were removed, and the upper bed nearly finished.

The locomotives were employed more particularly in conveying the earth to embankments of small height on the other side of the Vanvres cutting.

The line L K M D N, Fig. 1, represents the section of the temporary rails laid down for the conveyance of the earth cleared by the upper gullet, and carried on to the lower bed of the embankment. The line B D N is the section of the temporary rails used for clearing the lower gullet.

The operation of discharging the wagons at the extremity of the embankment was accelerated and facilitated by the employment of two moveable machines (*baleines*).

This ingenious apparatus, consisting of a kind of moveable scaffold, was invented by M. Clapeyron, engineer in chief of the Railways of St. Germain and of Versailles (right bank). We have given illustrations of these machines in Plate 39; and their mode of application will be found by turning to the explanation of the Plate.

A baleine was placed before each of the two lines of way abutting on the ex-

tremity of the embankment. A part of the earth was also discharged over an auxiliary lateral line, by means of wagons tilting in the front, and others tilting at the side, but the latter were principally employed.

The earth extracted from the other extremity of the cutting, having to be carried a short distance only, was conveyed by means of carts and small wagons drawn by horses.

Thus, in order to accomplish the object required, and to execute the cutting as rapidly as possible—

1st. We multiplied the points of filling or loading, by forming works for the removal of the earth on two stages, or lifts, at the same time, and contrived by costly but expeditious means to lengthen or extend the stations for loading.

2nd. We increased the rate of speed of the teaming as much as possible, partly by means of self-acting planes (*plans auto-moteurs*), and partly by the aid of locomotive engines, which were regulated according to the length of the lead and the inclination of the ways. The adoption of *plans auto-moteurs* also possessed the advantage of being more economical than the employment of horses for working very steep inclines.

3rd. We multiplied the points of discharge as much as possible, and rendered this operation very rapid, by depositing a part of the earth in the Val-Clamart, and raising the embankment in two separate layers.

If the embankment had been formed by a single lift, it would have been necessary, upon acquiring a certain height, to have given up the employment of the *baleines*, although so useful in facilitating and accelerating the operation of tipping the wagons.

The opening of the Clamart cutting was soon accomplished by the fortunate adoption of this plan. The quantity of earth excavated at one extremity during the summer months, and at the period of the greatest activity on the works, exceeded 30,000 cubic metres per month (39,241 cubic yards). From 1300 to 1400 cubic metres (from 1700 to 1832 cubic yards) were excavated on some days. This cutting was not completely finished until two years and a half after the commencement of the works, owing to the execution of the southern extremity having been retarded by the time lost in purchasing the land, by the construction of the viaduct on which the embankment was to be supported, and more especially by the want of capital.

The earthworks of the cutting of Clamart were costly, and although executed rapidly, the degree of despatch did not fully equal our expectations, for the following reasons:—

1. Great speed and great economy are found to be incompatible; one must be sacrificed to the other. Earth which might have been laid direct was handled about several times. The portion taken from the lower part of the gullet could not be conveyed into the wagons of the upper gullet by any other means than by several casts of the spade. The expense would have been reduced by placing a larger portion of this earth directly into the wagons of the lower gullet; but it would have increased the time for the execution of the works. The expense would have been equally reduced by leading away a portion of the earth arising from that cutting at once, in the wagons of the upper gullet, more especially that portion next the bottom.

2. The laying down of rails along the upper gullet rendered it necessary to prepare the bottom suitable to receive the same, which operation presented more difficulties than usual, as the soil at that height was found to consist of a very irregular bed of calcareous-siliceous flints, which could not be worked without difficulty, either by tools or with gunpowder. The presence of this bed would have been the cause of a considerable increase of expense, even if it had not occurred at the bottom of the gullet.

3. The extra precautions arising from the necessity of throwing down the mass E to the right of the upper gullet, and of part of the masses F, G, H, and I, situated to the left, in order to prevent slips of earth upon the way, induced the superintendent to allow the contractor an increased price. The throwing down of one portion of the remaining masses could not be so readily done in large quantities.

4. The working of the wagons, and the substitution of the empty for the loaded wagons along the gullet, and by a single way, being attended with great difficulty, consequently occasioned a great loss of time to the workmen employed in loading,—for instance, when loading the earth of the mounds, they could not dig the soil whilst looking out for the wagons. When two lines were laid down, the execution became easier, although the loaded wagons could not then be replaced by the empty ones so fast as could have been desired, and the operation required a great many changing places in the lines, the cost of purchasing which, and of laying down, was considerable. A part of the earth of the cutting H was carried direct to the wagons by barrows, but another part was of necessity deposited on the edge of the line, to wait for the empty wagons, which were then loaded with it by the spade. The whole of the earth of the cutting marked I, was conveyed by barrows along the line of the upper cutting.

5. Numerous accidents interrupted the works, which occasioned other *extra* expenses to the company. Some of these accidents were contingent upon the nature of the works which had been undertaken, others proceeded from a want of experience in the workmen and their superintendents. The wagon-drivers were unable to regulate the speed of the trains on the self-acting planes (*plans auto-moteurs*) at the commencement of the works, and frequently ran off the rails into the changing places situated between the upper and lower inclined planes. The wagons even sometimes passed over the head of the embankment, and destroyed the baleines, which did not possess sufficient solidity to bear the loaded wagons. We in vain placed moveable supports to strengthen the ways at the points of discharge, and directed by the most stringent orders that the ways should not be opened excepting at the moment of tipping. At other times the wagons ran off the rails, from the driver placed at the head of the train not detaching it from the rope with sufficient rapidity, on arriving at the top of the *plan auto-moteur*. Upon the works becoming more advanced, and the workmen acquiring greater experience, accidents of this nature were exceedingly rare, although it was often necessary to repair the pulley and rope of the upper *plan auto-moteur*. The rope also frequently broke as it became worn by the effects of friction.

6. The works were much prejudiced through the numerous disputes arising from the operation of teaming not having been included by the contractor of the earthworks. No contractor could, in fact, have been expected to take the responsibility of these new experiments which we have just described, but would have preferred, under all circumstances, in our opinion, to have executed the whole of the works by valuation (*en régie*) rather than divide them. The engineers proposed this course to the directors of the company; but the proposition did not meet their approval.

The working of the locomotives left nothing to be desired, since they were directed by the engineer, Georges, a very able man, who subsequently lost his life by the accident of May the 8th. Hicks' light four-wheeled engines were adopted, which were perfectly suitable for these purposes.

By our describing the difficulties which we encountered in the application of the principles applied at the cutting of Clamart, and concealing nothing, we shall enable such of our professional brethren who may be tempted to follow, to avoid the stumbling-blocks which lay in the way. It is seldom that the land is so valuable as that through which the cutting of Clamart was formed. Spoil-banks can be formed, and economy exercised both in time and money, when the ground

is less expensive. A large portion of the earth extracted from the upper part of a cutting may be deposited along the sides of the line, and the earth of the lower cutting may be conveyed in wagons, by a method similar to that which we have already described. We consider that the execution of a cutting of the greatest dimensions may be accomplished with extreme rapidity, and without excessive expense, by these methods. There is, moreover, reason to hope that rich and able contractors will soon be found in France the same as in England, possessing the requisite plant, tools, and tackle for the execution of the earthworks, who will afford the engineers proper co-operation, which those who constructed the first railroads in France had not the benefit of.*

STATEMENT OF PRICES.

The statements of prices which follow, refer to the execution of earthwork, and the removal of the soil by the aid of wagons drawn by horses and by locomotives. These statements have been made from notes collected during the execution of the cutting of Clamart, on the Versailles Railway (left bank), and may be applied on the following hypothesis:—

1. That the operation bears reference to the opening of a cutting containing 300,000 cubic metres (392,411 cubic yards) of soil, to be conveyed a distance exceeding 1000 metres (1093 yards).

2. That the cutting is situated in the environs of Paris.

3. That the period for the execution of the works is limited to 20 months, and that an amount of 600 cubic metres (784 cubic yards) of earth is to be excavated *per diem* of 10 hours.

4. That the iron tracks, on which the wagons run, have a gradient of 4 millimetres per metre (1 in 250), and that they are supported on sleepers, and formed with the rails intended for the permanent line.

5. That each of the wagons contains $1\frac{1}{2}$ cubic metres (1·962 yards) of earth; that they descend, when loaded, with the inclination of 4 millimetres per

* An average of 30,000 cubic metres (39,241 cubic yards) of earth was moved during the summer months in the cutting of Clamart from a single working (*chautier.*) This amount would undoubtedly have much increased if the earthwork had been executed by valuation (*en régie*), the same as the teaming. It appears that no more than 20,000 cubic metres (26,124 cubic yards), were tipped on the Rouen Railway, although executed very rapidly upon a bridge.

metre (1 in 250); that they re-ascend empty; that they are strongly constructed, and of the following weight:—

The body of wagon	1000 kilog.	..	(2205 lbs.)
The two pair of wheels, including axles	440 „	..	(970 lbs.)
Total	1440		(3175 lbs.)

That the diameter of the wheels is 0·50 metre (1 foot 8 inches), and that of the bearings of the axles 0·05 metre (2 inches), that these axles are formed of wrought-iron, and that they turn in cast-iron boxes filled with grease.

6. That three horses draw ten wagons with a speed of 25,000^{m} per diem of 10 hours.*

* The power required to draw 10 loaded wagons upon a slope falling 4 millimetres per metre (1 in 250), may be calculated thus :—

Ten empty wagons, at 1440 kilog. each, will weigh	14,400 kilog.	...	(31,752 lbs.)
These contain 150 cubic metres (196 cubic yards) of earth, weighing 1800 kilog. (3969 lbs.) each	27,000 „	...	(59,535 lbs.)
Total weight of 10 loaded wagons . .	41,400		(91,287 lbs.)

The resistance due to friction of wagons moving along a horizontal plane upon a railway has been found, after sufficient experience, to equal ·0067 of the weight to be drawn. It, therefore, follows that the amount of tractive power necessary to draw the 10 loaded wagons = 0·0067 × 41·400 . . . . 277·38 kilog. ... (611·6 lbs.)

As the slope falls 4 millimetres (1 in 250), the above quantity must be reduced by 41·400 × 0·004 . . . 165·6 „ ... (365·1 lbs.)

Remainder . . . . . . 111·78 (246·5 lbs.)

As there are three horses, each horse must consequently exert a force of traction equal to $\frac{111·78}{3}$ = 37·26 kilog. (82·15 lbs.) in taking the loaded wagons.

The resistance due to friction in taking up the empty wagons . .	0·0067
Ditto for the rise of 0·04	0·0040
Amounting to	0·0107

The weight to be drawn being 1440 kilogrammes (31·75 lbs.), the amount of traction is 14·400 × 0·0107 = 154·08, whence it follows that each horse exerts an effort of $\frac{154·08}{3}$ = 51·36 kilogrammes (113·2 lbs.), in drawing the empty wagons back. A horse, attached to an ordinary carriage, and travelling with a velocity of 36,000 metres in 10 hours, is capable of exerting a tractive force equal to 70 kilogrammes (154 lbs.): but, under the circumstances in which the loads are placed on a railway, a horse cannot exert an effort of more than 55 kilogrammes, (121 lbs.) [See Wood's Treatise on Railways, in which he gives 50 kilogrammes (110 lbs.) as the mean effort of horses on railways in the North of England.] Consequently, the number of horses requisite to draw the train on horizontal railway, will be $\frac{277·38}{55}$ = 5·04; and it would require an amount of tractive power equal to 0·0107 × 41400 = 442·98 kilogrammes (976·7 lbs.) to ascend a gradient of ·004 (1 in 250) and the number of horses necessary would be $\frac{442·98}{55}$ = 8·05

7. That a locomotive engine, with pistons 0^m 25 (9·8 inches) in diameter,* will draw 20 wagons at a rate of 100,000 metres (109,363 yards) per day of 10 hours.

8. That the time occupied in getting and in tipping is 10 minutes each journey, without reference to the length of the lead, or the system of traction.

The locomotive engines being subject to frequent injuries, it is always necessary to have more on the works than are strictly necessary; they may be generally taken at double the number that are absolutely required.

Whatever mode of drawing the wagons is adopted, whether by horses or by engines, the number of wagons required for getting and tipping always remains the same, but the number of those moving to and fro along the way is in inverse proportion with the velocity of the motive power employed to draw them.

Taking this hypothesis, and comparing the velocity of horses and of locomotive engines, we find that it would be necessary to have four times as many wagons to convey the earth, if horses are employed, as would be required with locomotive engines.

* The following were the principal dimensions of the engines employed on the earthworks of the cutting of Clamart:—

	M.		Feet.	In.
Diameter of pistons	0·253	...	(0	9)
Stroke of pistons	0·400	...	(1	$3\frac{1}{2}$)
No. of smoke tubes	76	Area of furnace in contact 17·60 metres (133 square feet 6 inches).		
Length	2·33		(7	7)
Interior diameter	0·037		(0	$1\frac{1}{4}$)
Length of the grate	0·70	Area of the grate 0^m 580 (6 square feet).	(2	3)
Breadth do.	0·98		(3	2)
			Square ft.	In.
Area of furnace in direct contact with the fire	3·40	...	(36	6)
Area of entire furnace	21·00	...	(226	0)
			Feet.	In.
Diameter of the body of the boiler	0·43	...	(1	5)
Diameter of each of the four wheels	1·35	...	(4	5)
Length of the rods joining the wheels, or distance between the axles	1·44	...	(4	$8\frac{1}{2}$)
Total length of the engine under the buffers	4·47	...	(14	8)

These engines were supported on four cast-iron wheels, and wooden frames between them, with a cylindrical fire-box covered by a semi-spherical dome, with hand gear and loose eccentrics.

The following calculations show the number of wagons that are required on the line by each mode of traction for a given distance.

For Teaming to a Distance of 1000 *metres* (1093 *yards*) *with Horses.*

The cubic quantity to be transported *per diem* being 600 metres (656 yards), which, as the wagons contain 1^{m} 50 (1·9 yards), consequently amounts to 400 wagon-loads *per diem*, which will require, due regard being paid to their returning after being tipped, a run of 800,000 metres (874,911 yards), the speed of the horses being 25,000 metres (15½ miles) per day, the number of wagons necessary will be $\frac{800,000}{25,000} = 32$. Thirty-two wagons will therefore be required for each 1000 metres (1093 yards); but for the first 1000 metres (1093 yards), it is necessary to have forty.

For Transporting with Locomotive Machines to a Distance of 1000 *metres* (1093 *yards.*)

With a locomotive engine moving at a velocity of 100,000 metres (62⅛ miles) *per diem* of 10 hours, the number of wagons necessary for the conveyance to a distance of 1000 metres (1093 yards) will be $\frac{800.000}{100.000} = 8$. The calculation gives 8 wagons; but since the engine can draw 20, it is necessary to employ this number at the least for the first 1000 metres (1093 yards.)

The engine being capable of running 100,000 metres (62⅛ miles) *per diem* with the 20 wagons, the total length of run for the wagons will be 2,000,000 metres (1242¾ miles); the number of wagons to be conducted per day being 400, it will be possible to run over a space of $\frac{2,000,000}{400} = 5000$ metres (5468 yards) at each trip, or, deducting their return after being tipped, a distance of 2500 metres, (2734 yards); thus a locomotive engine would be required and 20 wagons for every length of 2500 metres (2734 yards.)

The number of wagons necessary with horses would be 24. Taking the case as we have stated, it would be necessary that the engine should convey the earth a distance of 1666 metres (1822 yards), in order to derive the full benefit of its work. Since, in fact, the engine conducts 400 wagons; it will make 20 journeys *per diem*, and as it loses 10 minutes per journey, it will consequently lose a total of . . . . 200 minutes

Out of the day of ten hours, containing 600

The time during which it will be engaged in drawing will be, 400

The velocity of the engine being 10,000 metres ($6\frac{1}{4}$ miles) per hour, it will run over a distance of $\frac{10000 \times 400}{60} = 66{,}667$ metres (72,909 yards) in 400 minutes, and as it is required to make twenty journeys *per diem*, each journey will be $\frac{6667}{20} = 3333$ metres (3645 yards) without taking into consideration the return empty, 1666 metres, (1822 yards.)

We have allowed a high sum in the following list of prices, upon starting with 1000 metres (1093 yards), for the wear and tear of the engines and interest of capital, as it would be very difficult in a trial of this nature to prevent the loss of a considerable portion of the services of the engines, from the novelty of the undertaking. We have supposed that this loss would equal an extension in the conveyance of 666 metres (728 yards) beyond the 1000 metres (1093 yards) which would make about two centimes per metre. It would be necessary, in order to prevent this loss, or to diminish it, to vary the number of wagons upon the line every day, accordingly, to suit the length of the lead, which would have the effect of reducing the price of labour by a much greater amount than two centimes.

The following lists of prices are, strictly speaking, only applicable under precisely similar circumstances to those in which we may be supposed to have been placed, but they will serve as *data* in calculating other prices, according to the nature of the work to be executed.

As the cost of the *plant*, or tools and tackle, and some portions of the labour, does not increase in the same proportions as the cubic amount that may require to be executed, it therefore follows that there is an advantage in performing earthwork in large masses.

The Table E, which follows the lists of prices, shows that the expense of transporting to a distance of less than 2000 metres (2186 yards) is more with railway wagons than with ordinary carts, supposing the cubic quantity of cutting under 300,000 metres (392,426 cubic yards). The wagons, on the other side, possess an advantage over the carts, in being able to proceed in nearly all weather, of requiring fewer horses, and at the same time being able to be drawn by locomotives, and consequently, of rendering the works continuous, and independent of the accidental circumstances which are liable to arrest and suspend them.

No. 1, (A).—*Details of the cost of conveyance of a cubic metre* (1·31 *cubic yards*) *of earth transported with wagons drawn by horses, upon a way having a fall of* 4 *millimetres per metre.* (1 in 250.)

GENERAL PARTICULARS.				Price of a cubic metre, (35,317 feet) including excavating, loading in wagons, carrying and discharging 100 metres (109 yards.)	Price of conveying an additional 1000 metres (1093 yards.)
Art. 1st.—*Tools and Tackle.*	Cost Price.		Depreciation.	Francs.	Francs.
	Fr.		Fr.		
150 earth-wagons, at 650 fr. each	97,500	½	48,750		
(a) 3000 lineal metres (3280 yards) of double way, at 80 fr.	240,000	$\frac{1}{6}$	40,000		
40 temporary changing places, at 225 fr.	9000	½	4500		
Sheds and buildings	10,000	½	5000		
Tools for the workshops and laying down the way	8500	½	4250		
2 platforms for discharging, at 5000 fr.	10,000	½	5000		
	375,000		107,500		
Interest at 5 per cent. on 375,000 fr. for 20 months			31,250		
Total expenses, fr.			138,750		
Which gives for the cubic metre $\frac{138,750}{300,000}=$				0·4625	(b) 0·0113
Art. 2nd.—*Maintenance of Plant.*					
Such as wood, iron, steel, and nails, levers, oil, grease, &c.				0·0800	$\frac{1}{40}$ 0·0020
Workmanship				0·1200	$\frac{1}{40}$ 0·0030
LAYING DOWN, RAISING UP, AND MAINTENANCE OF TEMPORARY WAYS.					
Art. 3rd.—*Laying the Ways.*					
The difficulties experienced by the workmen during the execution of the works being allowed for, and the loss of time from their being obliged to lay down the way as the works advance, and merely a few rails at a time. Price, 0·70 cents for a single way, including the conveyance of the rails, &c. to the spot.					
We have reckoned above 3000 lineal metres (3280 yards) of double way, but as the works nearly always require the removal of the ways, and since there are two lines before the platforms being constantly removed, we must allow for laying 12,000 lineal metres (13,123 yards) of way at 0·70 cents per metre			8,400		
Laying of 80 changes of line at 20 fr....			1,600		
Total, fr.			10,000		
Which gives for the cubic metre (35,317 feet) at $\frac{10,000}{300,000}=0.0333$				0·0333	$\frac{1}{20}$ 0·0017
Art. 4th.—*Maintenance of the Ways.*					
A chief layer at 5 francs per day, and 7 layers at 21 francs, making together a total expense of 26 francs, which gives for the cubic metre $\frac{26}{60}$				0·04333	$\frac{1}{20}$ 0·0022
Art. 5th.—*Taking up of Temporary Ways and of the Rails and Sleepers.*					
12,000 lineal metres (13,123 yards), at the rate of 0·25 c.			3,000		
Taking up and conveyance of 80 changes of way, at 2.50 fr.			200		
Total, fr.			3,200		
Which gives for the cubic metre, at $\frac{3,200}{300,000}=$ ...				0·0107	$\frac{1}{20}$ 0·0005
Carried on				0·7498	0·0207

OBSERVATIONS.

NUMBER OF WAGONS.

For loading and unloading	80
On the line..	40
In reserve...	10
Under repair	20
	150

(a) When the length of the lead averaged 1000 metres (1093 yards), there were 6000 metres (6562 yards) of single way at the cutting of Clamart.

(b) Details of tackle for the conveyance of an additional 1000 metres (1093 yards):

32 wagons at 650 fr.	20,800	½	10,400
1000 metres (1093 yards) of way, at 80 fr.	80,000	$\frac{1}{6}$	13,333
10 changes of line, at 225 fr.	2,225	½	1,113
Stores and tools	1,000	½	500
	104,025		25,346
Interest at 5 per cent. on 104,025 fr. for 20 months....................................			8,869
Total..........................			34,015

Which gives for the cubic metre conveyed a distance of 100 metres (109 yards) $\frac{34,015}{300,000 \times 10}=$ 0.0113

GENERAL FEATURES.	Price of a cubic metre (35.317 cubic feet,) excavated, loaded in wagons, discharged and carried a distance of 100 metres (109 yards.)	Price of an additional conveyance of 1000 metres, (1093) yards.	OBSERVATIONS.
	Francs.	Francs.	
Brought forward	0·7498	0·0207	
TRANSPORT OF THE EARTH.			
(A) Art. 6th. Eight horses to take the wagons to the points where they are required to be taken by horses, to be loaded, which occasioned a daily expense of 48 francs, which gives for the cubic metre at $\frac{48}{600}$	0·0800	$\frac{1}{200}$ 0·0004	(A) There would be 12 horses required with locomotive engines instead of 8, as the horses employed in the conveyance are often able to take the wagons direct.
Art. 7th. Three horses costing 18 francs per day, and 2 drivers paid 6 francs, making a total of 24 francs, will draw 10 wagons containing 15 cubic metres, (18 cubic yards) of earth, a distance of 25,000 lineal metres (27,341 yards), which gives for the cubic metre $\frac{24 \times 2}{25 \times 15}$	0·1280	$\frac{1}{10}$ 0·0128	
Art. 8th. Time lost in loading and unloading, estimated at 10 minutes each journey, which gives for the cubic metre $\frac{24}{6 \times 10 \times 15}$	0·0266	$\frac{1}{200}$ 0·0001	
Art. 9th. Pushers and unhookers, 12 workmen at 2.50 francs, making a daily expense of 30 francs, which gives for the cubic metre at $\frac{30}{600}$	0·0500	$\frac{1}{200}$ 0·0003	
Art. 10th. Twelve workmen, being switchmen, cleaners of rails, and greasers, paid 24 francs, which gives for the cubic metre $\frac{24}{60}$ ...	0·0400	$\frac{1}{20}$ 0·0020	
GETTING, LOADING, RETAKING AND DISCHARGING THE EARTH.			
Art. 11th. Getting and loading the earth	0·6000	$\frac{1}{1000}$ 0·0006	We have allowed one-tenth on account of the inconvenience and loss of time occasioned by this mode of working.
Art. 12th. Retaking and throwing with shovels, or transporting the earth by barrows in order to load the wagons; taken at half the first getting	0·3000	$\frac{1}{1000}$ 0·0003	
Art. 13th. Discharging the wagons and arranging the points of discharge, being equal to 24 men, making a daily expense per day (of 12 hours) of 84 francs, which gives for the cubic metre at $\frac{84}{600}$	0·1400	$\frac{1}{2000}$ 0·0007	
SUNDRY EXPENSES.			
Art. 14. Workmen for various work, being equal to 16 workmen paid at the rate of 40 francs per day, which gives for the cubic metre at $\frac{40}{600}$	0·0667	$\frac{1}{50}$ 0·0013	The tippers arrange the points of discharge, and work 12 hours, the same as the other workmen. The respective advantages of discharging, with or without moveable platforms (*Baleines*) are discussed in a note following these tables.
Art. 15. Superintendents and keepers. Ten employed, paid at the rate of 30 francs per day, which is for the cubic metre at $\frac{30}{600}$	0·0500	$\frac{1}{50}$ 0·0010	
Total in francs	2·2311	0·0402	
Or equal to	(1*s.* 5*d.*)	(·02540	of a shilling) per cubic yard.

No. 2 (A′) *Details of the cost of conveyance of a cubic metre* (35.317 *feet*) *of earth, transported with wagons drawn by horses, upon the hypothesis of the railway being laid horizontal.*

GENERAL FEATURES.	Price of a cubic metre, (1·308 cubic yards,) excavated, loaded in wagons, discharged, and carried a distance of 100 metres, (109 yards.)	Price of an additional conveyance of 1000 metres (1093 yards.)	OBSERVATIONS.
Articles 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, and 15, as before stated	Francs. 2·0765	Francs. 0·0275	
TRANSPORT OF THE EARTH.			
Art. 7th. Five horses (see Note A, p. 140) costing 30 francs per day, and 2 drivers paid 6 francs, making a daily expense of 36 francs, will draw 10 wagons, carrying 15 cubic metres (18 cubic yards) of earth a distance of 25,000 lineal metres, (27,341 yards) which gives for the cube metre (35,317 cubic feet) at $\frac{56 \times 2}{25 \times 15}$=	0·1920	$\frac{1}{10}$ 0·0192	
Art. 8th. Time lost in loading and unloading, estimated at 10 minutes each journey, which gives for the cube metre at $\frac{36}{6 \times 10 \times 15}$=	0·0400	$\frac{1}{200}$ 0·0002	
Price per cube metre .... (1*s.* 5½*d.* per cubic yard.)	2·3085	0·0467	(·03 of a shilling per cubic yard.)

No. 3 (A″) *Details of the cost of conveyance of a cubic metre* (35·317 *feet*) *of earth, transported with wagons drawn by horses, upon the hypothesis of the railway being laid upon a rise of* 4 *millimetres per metre* (1 *in* 250.)

GENERAL FEATURES.	Price of a cubic metre, (35.317 cubic feet,) excavated, loaded in wagons, discharged, and carried a distance of 100 metres, (109 yards.)	Price of an additional conveyance of 1000 metres (1093 yards.)	OBSERVATIONS.
Articles 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, and 15, as before stated	Francs. 2·0765	Francs. 0·0273	
TRANSPORT OF THE SOIL.			
Art. 7th. Eight horses (see Note A, p. 140) costing 48 francs per day, and 2 drivers paid 6 francs, making altogether an expense of 54 francs, will draw 10 wagons carrying 15 cubic metres (18 cubic yards) of earth a distance of 25,000 metres (27,341 yards) per day, and the same for returning, which gives for the cube metre at $\frac{54 \times 2}{25 \times 15}$ = ...	0·2880	$\frac{1}{10}$ 0·288	
Art. 8th. Time lost in loading and unloading, valued at ten minutes each journey, which is for the cubic metre (35,317 cubic feet) at $\frac{54}{6 \times 10 \times 15}$ =............................	0·0600	$\frac{1}{200}$ 0·0003	
Price per cube metre .... (1*s.* 6½*d.* per cubic yard.)	2·4245	0·0564	(·036 of a shilling per cubic yard.)

No. 4, (B.) Details of the cost of conveyance of a cubic metre of earth (1·308 *cubic yards) transported with wagons drawn by locomotives upon a way having a fall of* 4 *millometres.*

GENERAL FEATURES.	Price of a cubic metre for excavating, loading, discharging, and conveying a distance of 100 metres (109 yards.)	Price of an additional conveyance of 1000 metres (1093 yards.)
	Francs.	Francs.

Art. 1st.—*Tools and Tackle.*

	Price.		Depreciation.
130 earth wagons, at 650 fr.	84,500	$\frac{1}{2}$	42,250
2 intermediate do. at 750 do.	1,500	$\frac{1}{2}$	750
3000 lineal metres (3280 yards) of double way, at 80 do.	240,000	$\frac{1}{6}$	40,000
40 temporary changes of line, at 225 do.	9,000	$\frac{1}{2}$	4,500
2 locomotives, at 33,000 do.	66,000	$\frac{1}{10}$	6,600
Buildings and sheds	15,000	$\frac{1}{2}$	7,500
Tools for the repairing shops	9,000	$\frac{1}{2}$	4,500
A tank, a pump, and a trough	1,000	$\frac{1}{2}$	500
2 discharging platforms, at 5000 fr.	10,000	$\frac{1}{2}$	5,000
	436,000		111,600
Interest, at 5 per cent., on 436,000 fr. for 20 months, fr.			36,333
Total expenses, fr.			147,933

	Francs.	Francs.
Which gives for the cubic metre $\frac{147,933}{300,000}$=	0·4931	(c) 0·0102
Art. 2nd.—*Maintenance of Plant.*		
Material as wood, iron, steel, nails, a vice, oil, grease, &c.	0·0840	$\frac{1}{40}$ 0·0021
Workmanship	0·1260	$\frac{1}{40}$ 0·0032
LAYING AND MAINTAINING THE TEMPORARY WAYS.		
Art. 3rd. *Laying the Ways,* (see table A)	0·0333	$\frac{1}{20}$ 0·0017
Art. 4.—*Maintenance of Way.*		
Chief layer at 5 francs per day, and 9 layers, paid 27 francs, making, together, 32 francs which is to maintain all the ways, which gives for the cubic metre $\frac{32}{600}$=	0·0533	$\frac{1}{20}$ 0·0027
Art. 5th. *Taking up the Ways and Conveyance of the Rails and Sleepers* (see table A)	0·0107	$\frac{1}{20}$ 0·0005
TRANSPORT OF THE EARTH.		
Art 6th. 12 horses to bring the wagons to the locomotives, making an expense of 72 francs per day, which gives for the cube metre at $\frac{72}{600}$=	0·1200	$\frac{1}{200}$ 0·0006
Art. 7th. A locomotive with cylinders 0.28^{m} (11 ins.) diameter, and wheels of 1.25^{m} with a driver and stoker, making, for a day of 10 hours, including the wages of the men, an expense of 94 francs for coke, coal, oil, water, and petty expenses .... 91.00 fr. The engine drew with a velocity of 10,000^{m} an hour a train of 20 wagons, containing 30 cubic metres (39 cubic yds.) of earth, driven by 3 conductors, who received .... 10.00 Total .... 101.00 Whence it follows that a cubic metre of earth carried a distance of 1000 (1093 yds.) cost, including the return of the wagons after being emptied $\frac{101 \times 2}{100 \times 30}$=	0·0673	$\frac{1}{10}$ 0·0067
Art. 8th. Time lost, loading and unloading, ten minutes per journey, which gives for the cube metre $\frac{101}{6 \times 10 \times 30}$ =	0·0561	$\frac{1}{200}$ 0·0003
Art. 9th. Pushers and unhookers of the wagons (see table A)	0·0500	$\frac{1}{200}$ 0·0003
Art. 10th. Switchmen, cleaners of rails, and greasers (see table A)	0 0400	$\frac{1}{20}$ 0·0020
Art. 11th. Getting and loading, regetting and discharging the soil (see table A)..	0.6000	$\frac{1}{1000}$ 0·0006
Art 12th. Retaking	0.3000	$\frac{1}{1000}$ 0·0003
Art. 13th. Discharging	0·1400	$\frac{1}{200}$ 0·0007
SUNDRY EXPENSES.		
Art. 14th. Arrangers for the different works (see table A)	0·0667	$\frac{1}{50}$ 0·0013
Art. 15th. 12 superintendants and keepers employed and paid 36 fr. per day, which gives, per cubic metre $\frac{36}{600}$	0·0600	$\frac{1}{50}$ 0·0012
Total	2·3005	0·0344
Or equal to..................	(1*s.* 6*d.*)	(·021 of a shilling) per cubic yard.

OBSERVATIONS.

NUMBER OF WAGONS.

Loading and discharging	80
On the way	20
In reserve	10
Under repair	20
Total	130

(c) Depreciation of material for the transport of 2500 metres additional.

2 locomotives	66,000	$\frac{1}{10}$	6,600
1 shed for do.	5,000	$\frac{1}{2}$	2,500
20 earth wagons at 750 fr.	15,000	$\frac{1}{2}$	7,500
1 intermediate do.	750	$\frac{1}{2}$	375
2500 lineal metres of double way at 80 fr.	200,000	$\frac{1}{6}$	33,333
15 changes of line at 225 fr.	3,375	$\frac{1}{2}$	1,683
Stores and tools	2,000	$\frac{1}{2}$	1,000
	292.125		52,991
Interest, at 5 per cent., on 292.125 for 20 months			24,831
			77,822

Which gives for the cubic metre $\frac{76.168}{300.00 \times 2500}$ = 0·0102

No. 5 (B′). *Details from the data where the transport takes place upon a level way.*

GENERAL FEATURES.	Price of a cube metre for excavation, loading on wagons, discharging, and conveying a distance of 100 metres (109 yards).	Price of an additional conveyance of 1000 metres (1093 yards).	OBSERVATIONS.
Articles 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, and 15, as before stated	Francs. 2·1771	Francs. 0·0274	
Art. 7th. A 10-horse power locomotive, being an expense per day of 101 francs, which will draw with a velocity of 10,000 metres (6 miles) per hour, a train of 12 wagons, carrying 18 cubic metres (24 cubic yards) of earth, which gives for the cube metre $\frac{101 \times 2}{100 \times 18}$ = ...	0·1122	$\frac{1}{10}$ 0·0112	
Art. 8th. Time lost in loading and discharging, 10 minutes per journey, which gives for the cubic metre $\frac{101}{6 \times 10 \times 18}$ = ...	0·0935	$\frac{1}{20}$ 0·0005	
Cost per cubic metre......... (1*s.* 6¼*d.* per cubic yard.)	2·3828	0·0391	(·0249 of a shilling per cubic yard.)

No. 6 (B″). *Details from the data where the transport takes place upon a way with a rise of* 4 *millimetres.*

GENERAL FEATURES.	Price of a cubic metre for excavation, loading and discharging, and conveying a distance of 100 metres (109 yards).	Price of an additional conveyance of 1000 metres (1093 yards).	OBSERVATIONS.
Articles 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, and 15, as before stated	Francs. 2·1771	Francs. 0·0274	
Art. 7th. A 10-horse power locomotive, being an expense per day of 10 hours, of 101 francs, which will draw with a speed of 10,000 metres (6⅕ miles) per hour, a train of 7 wagons, carrying 11 cubic metres (14 cubic yards), which gives for the cube metre $\frac{101 \times 2}{100 \times 14}$ = ...	0·1836	$\frac{1}{10}$ 0·0184	Seven wagons carry 11·25 cubic metres, taken correctly.
Art. 8th. Time lost in loading and discharging, 10 minutes a journey, which gives for the cubic metre $\frac{101}{6 \times 10 \times 11}$ = ...	0 1530	$\frac{1}{200}$ 0·0008	
Cost per cubic metre......... (1*s.* 7¼*d.* per cubic yard.)	2·5137	0·0466	(·0275 of a shilling per cubic yard.)

No. 7 (C) *Details of the cost of conveyance of a cubic metre* (1·308 *cubic yards*) *of earth, the wagons moving upon self-acting planes* (plans automoteurs) *of* 200 *metres* (219 *yards*) *long, having a fall of* 0.05 *per metre,* (1 *in* 20.)

GENERAL FEATURES.				Cost of a cubic metre, excavated, loaded in wagons, unloaded, and carried a distance of 1000 metres, (1093 yards.)	OBSERVATIONS.
Art. 1st.—*Tools and Tackle.*	Cost price. (francs)		Depreciation. (francs)	Francs.	These calculations have been made on the supposition that the wagons, after arriving at the bottom of the self-acting plane, (*plan automoteur*,) would continue to run for 800 metres (875 yards further.) They might be carried to a greater distance, but it would be necessary to start them with a speed which might be dangerous.
Wagons, rails, workshops, sheds, and discharging platform, as No. 1	375,000	...	107,500		
Additional for repairs of discharging points	2,500	1	2,500		
Self-acting planes (*plans automoteurs*) and ropes.....................................	6,500	$\frac{4}{5}$	5,200		
	384,000		115,200		
Interest at 3 per cent. for 20 months on 399,000..			32,000		
Total expenses, fr.			147,200		
Which gives for the cubic metre $\frac{147,200}{300,000}$ = ...				0·4907	
Art. 2nd.—*Maintenance of Plant.*					
Such as wood, iron, steel, nails, screws, grease, oil, &c..........				0·0840	
Labour				0·1260	
LAYING, TAKING UP, AND MAINTAINING THE TEMPORARY WAYS.					
Art. 3rd. Laying the rails (see Table A)				0·0333	
Art. 4th. Taking up ditto (ditto)				0·0107	
Art. 5th. Maintaining the ways, (ditto)				0·0433	
CARRIAGE OF EARTH					
Art. 6th, 7th, and 8th. Twelve drivers and 15 horses, making a daily expense of 126 francs, who will conduct the whole of the wagons, which gives for the cubic metre $\frac{126}{600}$ = ...				0.2100	
9th. Pushers and unhookers of the wagons (see Table A)......				0.0500	
10th. Switchmen, cleaners of the rails, and greasers (do.) ...				0.0400	
GETTING AND LOADING, RETAKING AND UNLOADING THE EARTH.					
11th. Getting and loading the earth (see Table A)				0·6000	
12th. Retaking ditto (ditto)				0·3000	
13th. Discharging ditto (ditto)				0·1400	
SUNDRY EXPENSES.					
14th. Workmen for the different works (see Table A).........				0·0667	
15th. Superintendents and guards (see Table B)				0·0600	
Total				2·2547	(1*s.* 5¼*d.* per cubic yard.)

It will be necessary to have recourse to self-acting machines, (*plans automoteurs*,) whenever circumstances require the earth to be lowered from a great height, for if it was terminated by a simple inclined plane, it would be necessary to take up the empty wagons with horses, which would occasion an enormous expense, a delay in the work, and more frequent loss of time.

It would have been necessary to have employed 20 horses in returning the wagons upon the cutting of Clamart, and upon three planes, at a cost of 120 francs per day.

(E.)—*Table of Comparison of the Cost of Transporting Earth upon a level way.*

Distance of Transport.	Transports by Carts		Transports by Wagons, drawn	
	Upon an Earth Road.	Upon a Hard Road.	With Horses.	With Locomotives.
Metres. Yards.	Francs. s. d.	Francs. s. d.	Francs. s. d	Francs. s. d.
1000 (1093)	2·2195 (1 10)	1·7580 (1 5½)	2·3085 (1 11)	2·3828 (1 11½)
1500	2·7955	2·1470	2·5420	2·5783
1600	2·9107	2·2248	2·5887	2 6174
1700	3·0259	2·3026	2·6354	2·6565
1800	3·1411	2·3804	2·6821	2·6956
1900	3·2563	2·4582	2·7288	2·7347
2000 (2186)	3·3715 (2 9½)	2·5360 (2 1)	2·7755 (2 4)	2·7738 (2 3½)
3000	4·5235	3·3140	3·2425	3·1648
4000	5·6755	4·0920	3·7095	3 5508
4500	6·2515	4·4810	3·9430	3·7513
4600	6·3667	4·5588	3·9897	3 7904
4700 (5140)	6·4819 (5 5)	4·6366 (3 10½)	4·0364 (3 4¼)	3·8295 (3 2)

The prices given in this table comprise expenses of every kind, as the cost of labour for digging, loading, conveying, unloading, levelling, cost of plant, and sundry prices.

The cost of the earth transported in wagons, has been calculated before in Table No. 2, A′, and No. 5, B′.

Respecting the cost of conveying the earth in carts, we have supposed that a cart drawn by two horses, and driver, would be paid 14 francs per day of 10 hours. That the time lost in loading and discharging would be $\frac{1}{10}$ of a day. That two horses could convey 0.80 cubic metres of earth a distance of 36,000^{m} (39,371 yards) per day upon an earth road, so that upon a well maintained way two horses would convey 100 cubic metres, a distance of 36,000^{m} ($22\frac{1}{3}$ miles) per day.

It will be seen from the above table that the conveyance of earth by carts is far from presenting advantages in respect to economy. In looking over the details of the expense of conveyance, we observe that the expense of traction with wagons is much lower. But on the other hand, the wagons cannot always approach the points of loading like carts. Additional expenses frequently arise in loading, and it is the same case in unloading; and finally, the conveyance is burthened by the expenses of laying, maintaining, and depreciation of way, which are considerable, and do not exist when the conveyance is performed by carts.

The conveyance of great masses of earth by wagons does not present much advantage as respects economy, when the distance is within 1000^m (1093 yards,) but they are often employed for less distances, because earth roads are impracticable for carts during the bad season, and in the rainy days, so frequent at all seasons, whilst it is seldom necessary to suspend the works with wagons upon railways.

The extra expenses were much increased at the cutting of Clamart, on account of the means employed to accelerate the work, which exceeded everything which had been previously done. These expenses would be considerably reduced, where the same rapidity of execution is not required.

SUNDRY NOTES.

Expense of a locomotive engine, with cylinders of 0·28 *metres* (11 *inches*) *in diameter, and wheels* 1 *metre* 25 (4 *feet* 1 *inch*), *employed at the cutting of Clamart, and employed in drawing* 20 *wagons, loaded with earth, a distance of about* 2000 *metres* (2187 *yards*), *for a period from the* 1*st to the* 15*th August, comprising* 14 *days' work, at the rate of* 12 *hours per day.*

General Particulars.	Number.	Price.	Total Amount.	Observations.
	H.	Francs.	Francs.	
Hectolitres of coke	344·50	2·50	861· 25	
Do. charcoal......	20·50	3·00	88· 50	
Water casks, holding 0·85	96·00	2·50	240· 00	
Kilogrammes of oil	24·00	3·00	72· 00	
Petty expenses and maintenance			25· 25	
Total cost of articles consumed			1287· 00	
Conductor at 200 francs per month... 100 fr. Stoker at 120 francs per month 60			160· 00	
Sum Total for Engine			1447· 00	
The engine drew 20 wagons, with 3 conductors, paid 12 francs per day, which makes for 14 days			168· 00	
Total expense			1615· 00	
The number of wagons conveyed was 5760, each wagon, therefore, cost $\frac{1615}{5760}$ = ...			0·2804	This data, having been taken under favourable circumstances, cannot, therefore, be considered as a mean. The prices should be increased by about one-fifth.
And as each wagon contained 1·47 cubic metres of earth, the cubic metre amounted to $\frac{1615}{5760 \times 147}$ (or ·118 of a shilling per yard)			0·1907	

COST OF EARTHWAGONS.

The earthwagons were employed on the Versailles Railway, (left bank,) and tipped before. See No. 1, Plate 43. The cost amounted to 640 francs, 65 cents, which was subdivided in the following manner :—

CUBIC AMOUNT OF WOOD IN THE FRAMING.

	Length.	Height.	Breadth.	Cube.	No.	Cube.	General Cube.
	m	m	m	m		m	m
Side pieces A. (See Plate)	2·74	0·22	0·11	0·066308	2	0·132	0·291
Cross sleepers B	1·90	0·20	0·10	0·038000	2	0·176	
„ ledges C	0·63	0·22	0·11	0·015246	2	0·030	
Tipping ledges D	0·94	0·18	0·11	0·018612	2	0·037	
Cross-piece for brake E	1·00	0·10	0·08	0·008000	1	0·008	
Shoe of brake S	0·42	0·20	0·10	0·008400	1	·008	

CUBIC AMOUNT OF WOOD IN THE BODY.

	Length.	Height.	Breadth.	Cube.	No.	Cube.	General Cube.
Side pieces F	2·30	0·15	0·10	0·034500	2	0·069	0·199
Cross sleepers H	2·10	0·11	0·10	0·023100	2	0·046	
Small cross sleepers K	2·10	0·11	0·07	0·016170	2	0·032	
Ledges L	0·50	0·18	0·10	0·009000	2	0·018	
Ledge for brake M	0·70	0·11	0·10	0·007700	2	0·015	
Side pieces R	0·65	0·10	0·06	0·003900	5	0·019	
							0·490

	Fr.	Cts.
This gives, at the rate of 109 fr. per metre	53	40
The oak planks for the body of 0·04 in thickness, at 6·56 fr. per square metre	52	50
Making	50	"
Mounting	30	"
Iron-work, 143·26 kilog. (316 lbs.) at 1 fr. 20 c. the kilog.	174	30
4 pieces of cast iron for pivots, 32·50 kilogs. (72 lbs.) at 0·60 fr. per kilogramme	19	50
Total amount of carpentry and iron work	379	70
2 axles weighing 66 kilog. and making each 132 kilogs. (291 lbs.) at 1 fr. per kilogramme	132	"
4 cast-iron wheels cast in a shell, weighing 68 kilogs. each, and making 272 kilogs. (600 lbs.) at 0·38 fr. per kilog. (2·205lbs.)	103	35
4 grease boxes weighing 7 kilogs. each, and making 28 kilogs. (61lbs.) at 0·50 fr. per kilog..	14	"
4 pins weighing 1 kilog. (2·205 lbs.) at 1 fr. per kilogramme	4	"
4 iron hoops weighing each 3 kilogs. and making 12 kilogs. (26lbs.) at 0·60 fr. the kilogramme	7	60
Total amount of the wheels, axles, &c.	260·	95
The total cost of a wagon therefore amounts to	640·	65 (£26 13s. 9½d.)

The earth wagon, tipping at the side, and represented by No. 2, on the same Plate, cost 664 francs 80 cents (£27 14*s*.), being subdivided in the following manner:—

CUBIC AMOUNT OF WOOD IN THE FRAMING.

	Length.	Height.	Breadth.	Cube.	No.	Cube.	General Cube.
	m	m	m	m		m	
Side pieces	2·66	0·20	0·12	0·064	2	0·128	
Cross sleepers	2·00	0·17	0·10	0·034	2	0·068	
Centre cross sleepers	1·91	0·18	0·10	0·034	1	0·034	
Ledges	0·38	0·20	0·10	0·011	2	0·022	
Tipping ledges	0·74	0·17	0·10	0·013	2	0·026	0·410
Small block piece	0·36	0·12	0·10	0·004	1	0·004	
Large ditto	0·46	0·20	0·10	0·090	1	0·090	
Diagonal pieces	1·05	0·19	0·03	0·006	2	0·012	
Cross piece for brake	1·00	0·10	0·08	0·008	1	0·008	
Shoe of brake	0·42	0·20	0·10	0·008	1	0·008	
CUBIC AMOUNT OF WOOD IN THE BODY.							
Side pieces	2·30	0·15	0·10	0·034	2	0·068	
Cross sleepers	2·08	0·11	0·10	0·023	2	0·046	
Small cross sleepers	2·08	0·10	0·05	0·010	2	0·020	0·186
Ledges	0·45	0·20	0·10	0·009	2	0·018	
Tipping ledges	0·70	0·10	0·10	0·007	2	0·014	
Side pins	0·65	0·10	0·06	0·004	5	0·020	
Total cubic amount of wood							0·596

	Fr.	Cts.	
This gives at the rate of 109 francs per cubic metre	64	95	
Oak planks for the body, 0·04 in thickness, at 6 fr. 50 c. per square metre	52	50	
Making	50	00	
Mounting	30	00	
Ironwork, 155 kilog. (342 lbs.) at 1 fr. 20 c. the kilog. (2·205 lbs.)	186	90	
4 pieces of cast-iron for pivots, 32·60 kilog. (719 lbs.) at 0·60 fr. the kilog.	19	50	
Total cost of wood and ironwork	403	83	
Add for wheels, axles, &c.	260	95	
The total cost of a wagon, comprising wheels, axles, &c.	664	80	(£27 15*s*.)

We conclude our account of the cost of earth wagons by the following details of the weight of the ironwork and the nature of the iron employed in the manufacture:—

The weight of Iron work required to complete 10 *earth wagons* (*tipping before.*)

	Weight in kilogrammes.	Shape.	Quality.	Dimension of the iron in lines.	Price of coarse iron per 100 k. (220lbs.)
	k.				fr.
10 Breaks	131·625	Square	Roche	15·15	56
20 Tilting pivots	83·375	Flat	do. 1st quality	„	„
10 Shafts to breaks.	15·800	Square	Roche	„	56
40 Bearing chains	49·500	Round	Grenelle	12·12	60
20 Draw links and rings	73·	....	Roche	24·11	56
20 Centre pin irons	33·	Flat	Grenelle	33· 4	60
20 Large pins	37·500	„	„	33· 4	„
10 Square pins and fillets . . .	19·	„	„	22· 5	„
20 Hangings and hinges	74·500	„	Basse-Indre	24· 5	50
40 Large ferrules to side pieces. .	59·	„	Grenelle	14· 4	60
20 Small ferrules to brakes . . .	10·500	„	„	12· 3	„
10 Stays	15·500	„	„	14· 4	„
40 Square irons to body	43·250	„	Basse-Indre	24· 2½	38
10 Square irons to turning piece .	6·750	„	„	„	„
40 Distancing fillets	21·500	„	„	24· 2½	50
20 Circular staples	15·	„	Grenelle	14· 4	60
20 Tipping bolts	26·	Round	„	16·16	„
20 Circular straps fitting to eye pieces	55·	Flat	Basse-Indre	24· 5	50
20 Ditto to turning pieces . . .	34·	„	Grenelle	24·24	60
10 Leading turns	9·775	„	„	„	„
10 Conductors and pins	49·500	„	„	„	„
10 Bolts to break	4·	„	„	12· 3	„
20 Large bolts of 2·28 (9 lines diam.)	129·300	Round	„	9· 9	„
20 Bolts „ 0·44 „ .	31·	„	„	„	„
20 „ 0·42 „ .	27·775	„	„	„	„
20 „ 0·41 „ .	26·	„	„	„	„
40 „ 0·40 „ .	57·550	„	„	„	„
20 „ 0·39 „ .	24·125	„	„	„	„
10 „ 0·37 „ .	12·	„	„	„	„
40 „ 0·29 „ .	43·	„	„	„	„
40 „ 0·27 „ .	38·500	„	„	„	„
10 „ 0·20 „ .	8·250	„	„	„	„
40 „ 0·16 „ .	29·	„	„	„	„
20 „ 0·31 (7lines diam.)	13·	„	„	7· 7	„
20 „ 0·23 „ .	9·250	„	„	„	„
60 0·16 & 0·19 „ .	31·	„	„	· 6	„
80 Bolts for greaseboxes (6 lines diam.)	14·130	„	„	6·	„
50 Bolts of 0·13 „ .	9·500	„	Grenelle of	„	„
30 „ 0·11 „ .	8·250	„	inferior qua-	„	„
50 „ 0·09 „ .	7·800	„	lity, for bolts	„	„
125 „ 0·07 „ .	16·120	„	which are	„	„
40 „ 0·05 „ .	4·750	„	not much	„	„
160 „ 0·05 „ .	19·750	„	strained.	„	„
10 Stirrup bolts to break. . . .	3·500	„		„	„
200 Washers for bolts	9·250	„		„	„
150 Ditto for small bolts	1·775	„			
50 Small double pins	1·	„			
Total weight of iron work for 10 wagons . . .	1452·640	(3203lbs.)			

The contract price being 1fr. 20c. per kilogramme, the iron work for 10 wagons would consequently cost 1743fr. 15c., or 174fr. 34c. (7*l.* 5s. 3d. for each wagon.)

The Grenelle iron made at the Grenelle Iron Works near Paris, is of superior quality. It is made of old iron of sufficient strength and hardness, and sells at 60 fr. per 100 kilogrammes.

The Basse-Indre iron consists of iron manufactured with rolling mills, and that of good quality sells at 50 fr.

The Roche is the iron of Champagne, made with charcoal, and sells at 56 fr. per 100 kilogrammes.

The weight of Ironwork required to complete 10 *earth wagons* (*tipping sideways.*)

	Weight in kilogrammes.	Observations.
10 Breaks	130·500	The qualities and dimensions of the iron are the same as the similar pieces in the wagon tipping forwards.
20 Tilting pivots	87·500	
10 Shafts to breaks	15·500	
40 Bearing chairs	51·750	
20 Draw links and rings	73·750	
20 Centre pin irons	35·250	
20 Large pins	38·250	
10 Pins to breaks	20·250	
20 Hanging and hinges	73·500	
40 Large ferules	55·750	
10 Small ferules to breaks	5·000	
10 Stirrups to breaks	15·500	
40 Square irons to bodies	49·750	
40 Distancing fillets	21·500	
20 Circular staples	14·000	
20 Tipping bolts	25·000	
20 Circular straps fitting to eye-pieces	55·000	
20 ,, ,, turning-pieces	34·500	
10 Leading turns	15·500	
10 Conducters and pins	47·000	
20 Large bolts ·30 (9 lines diam.)	119·550	
10 ,, 1·98 ,,	52·250	
20 ,, 0·58 ,,	36·250	
20 ,, 0·40 ,,	26·000	
20 ,, 0·40 ,, }	65·500	
30 ,, 0·40 ,, }		
20 ,, 0·33 ,,	21·750	
20 ,, 0·31 ,,	23·000	
20 ,, 0·27 canted with inclined heads	20·000	
20 ,, 0·27 ditto with square heads	20·000	
30 ,, 0·27 with square nuts	28·750	
80 ,, 0·27 with canted nuts	77·750	
20 ,, 0·18	14·500	
10 Bolts 1·95 (7 lines diam.)	32·750	
10 ,, 0·40 ,,	8·000	
20 ,, 0·33 ,,	13·500	
20 ,, 0·25 ,,	11·250	
40 ,, 0·25 ,,	20·500	
10 ,, 0·17 with square heads	4·250	
80 ,, of grease-box, (3 lines diam.)	15·250	
50 ,, 0·13 (*Spikes*)	10·250	
50 ,, 0·11	9 000	
50 ,, 0·10	8·000	
125 ,, 0·07	17·500	
40 ,, 0·16	5·750	
160 ,, 0·05	20·750	
100 Washers for bolts of 9 lines diam.	4·750	
100 ,, ,, 7 ,,	1·500	
75 ,, ,, 5 ,,	,,	
Total weight of ironwork for 10 wagons	1557·500	(3434lbs.)

The contract price was 1fr. 20c. per kilogramme. The iron work for ten wagons would, consequently, cost 1,869 frs.; or 186 fr. 90 c. (£7 15*s.* 7*d.*) for each wagon.

The same iron may be now obtained at the price of 1 fr. per kilogramme.

OBSERVATIONS ON THE VARIOUS METHODS EMPLOYED IN UNLOADING WAGONS FOR EARTHWORK.

By M. Brabant.

The method requisite to be employed in unloading earth wagons is entirely dependent upon the work to be executed.

The earth removed is in general laid out in the form of a mound, of moderate width, but of great length.

The earth wagons employed to form the embankment may be discharged by means of baleines (see Plate 39, and Description), or by siding places, each of which serve to remove the wagons out of the way after being discharged.

No apparatus is necessary when the tipping is conducted without a baleine; but it is less expeditious, and scarcely permits of a hundred wagons being discharged *per diem* of twelve working hours upon one line; so that it would be requisite to increase the number of ways, in order to advance with any celerity, which is expensive, and not always practical.

Thus, when earthwork is executed by a single lift, the top is necessarily so narrow, that no more than two or three teaming places can be obtained, nor upwards of 200 to 300 wagons (consequently) tipped *per diem.* It is even rare that so many are discharged.

But if the embankment is high, and two or three lifts can be laid out, the lower one will be of great width, by which as many as six ways can sometimes be laid down, on which from 400 to 500 wagons *per diem* can be discharged. Every line does not, however, in this case accommodate 100 wagons, since this would crowd it, and occasion difficulty in the management, which becomes complicated in proportion as the number of wagons create stoppages.

The system of tipping the wagons without a baleine is applicable with small heights and in loose soils, also where short cuttings follow short embankments, where the height varies suddenly, as some portions of the Belgium line, between Varennes and Liege, where the volume of earth to be moved, although small, was very much dispersed. It is necessary to find more simple means in these cases,

which can be applied simultaneously at every part where work is required to be executed, rather than powerful agents and expensive apparatus.

Thus it would not be necessary, under these circumstances, to employ wagons, unless the transport with carts should be impracticable.

The wagons may be tipped more rapidly with baleines than with siding places. The rate of progress attainable with this plan depends upon the nature of the work to be executed and the baleines employed.

Where extensive cuttings are required to be made, on which the accomplishment of the railway depends, it is requisite to employ rapid means, similar to those employed on the railways of St. Germains and Versailles, on which twenty-four labourers tipped ten wagons in four minutes; but the baleines cost 4500 francs (£187 10*s.*), and involved very expensive repairs.

These great baleines are used in the construction of embankments of 5 to 10 metres high, and, taking into account the loss of time, do not discharge more than 40 wagons, containing 1^{m} 50 cube each (1·96 cube yards), per hour; but this amount is considerable, compared with the quantity discharged without the assistance of baleines. The cost of unloading and spreading comes to about 15 cents per cubic metre (1*d.* per yard).

At the commencement of the campaign of 1838, and under very favourable circumstances, as many as 900 wagons, each containing 1^{m} 50 (1·96 cube yards), were tipped *per diem* of fifteen hours' labour, on the Versailles Railway (left bank), which makes a cubic quantity of 1350 metres (1765¾ cubic yards). If both sides of the cutting had been opened in a similar manner, the cubic amount would have equalled 2×1350 metres $= 2700$ metres (3531 cubic yards).

Small baleines of 12^{m} (39 feet 4 inches) long, and 6^{m} (19 feet 8 inches) high, were used on the Lille Railway, on the Belgian frontier, which only cost 300 francs (£12 10*s.*), and were of great service.

They were sufficient to effect the discharge of all the earth arising from the cuttings, even in places where the height of the embankment was from 6 to 10 metres, (19 feet 8 inch. to 32 feet 10 inch.) It was necessary to construct certain embankments at these places at convenient heights, to receive the baleines, and render them effective. These embankments did not occasion any increase of expense, as they were formed, by means of the side cuttings required in completing the embankment. It is necessary, in making the side cuttings, to give a preference to the lowest places.

Twelve workmen would discharge 5 wagons in 6 minutes with these baleines, the number of wagons discharged on each baleine being generally 20 per hour.

Nine hundred wagons containing 1.25^{m} each (1·63 cubic yards) was the regular number discharged *per diem* of 24 hours continuous labour, night as well as day, on the Ogiers cutting, during the fine season of the year 1842, with 4 baleines, placed in pairs on each side, which makes a cubic quantity of 1125^{m} (1456¾ cubic yards.)

The results would have been much greater if the ways had been good; but the line being formed with iron bars placed edgeways for want of rails, the operation of teaming could not receive full development.

The above, indicating the number of wagons tipped, although less than if the trains could have been discharged continuously, still exceeds the average, even during the fine season; since impediments and accidents were constantly occurring, which occasioned (*more or less*) delays, so that the advantages and capabilities of the method employed in the tipping were never more than partially obtained.

We must not reckon on more than a moiety of the results given above, in winter, taking the average.

Baleines are the constant cause of delay, as it is necessary to move them forward once, twice, or even as many as three times in the course of the day, but they can generally arrange them so as to prevent delay, *more or less*, by performing this portion of the work as frequently as possible during the meal hours and by night, by which there is not much time lost, unless the work is continued during the twenty-four hours.

When the baleines are moved forward during the work, one only should be advanced at a time, the wagons being discharged on the other baleine; the men, moreover, ought always to manage, so as to tip the wagons towards the sides and between the ways, during the operation of advancing the baleines.

The requisite time for moving a well-made baleine forward ought not to exceed half an hour; but when the baleines are badly constructed, or are allowed to get too much encumbered, or are left to unskilful and inexperienced workmen, the operation occupies as much as two hours. In order to prevent these delays, it is necessary to choose a gang of select labourers, and reserve them constantly for tipping the wagons and moving the baleines forward.

The height of embankment capable of being made with baleines is from 2 to 9 metres (6 feet 7 inches to 29 feet 6 inches).

When the embankments are less than 2.00^{m} (6 feet 7 inches), the men are obliged to change the baleines frequently, which occasions a great loss of time,

When, on the contrary, they are more than 9.0^{m} (29ft. 6in.) high, the result

is, that larger baleines are required, which are consequently difficult to manage and to keep in their places properly.

When it is necessary to raise an earthwork of great length, of a height exceeding 10^{m} (32ft. 10in.), it is advisable to make it in two lifts, or to raise the soil beneath the baleines.

If the embankments required to be executed to fix the baleines are trifling, or a portion has to be made by side cuttings, or, finally, if it is upon an unsettled soil, the level of which is very irregular, it is preferable to raise the soil; and the embankment requiring to be first made, should be taken either from side cuttings on the adjacent land, or on the site of the road, or be composed of earth brought by wagons from other spots.

The number of baleines may be diminished, or entirely dispensed with, by forming a narrow embankment, which can be rapidly widened afterwards by means of a long file of wagons tipping at the side, either by a baleine in the middle, or by aid of a side cutting, but it is generally more convenient, and, what is of greater importance, more expeditious to employ baleines, and to reserve the side cuttings for the upper portion, when the height of the proposed embankment is very great.

It is generally preferable to tip the wagons on the baleines, but there is no rule to prevent the choice of whatever plan is most convenient. This choice depends on a variety of circumstances, which must be studied and carefully compared before adopting any method. We may, however, in most cases, comply with the following principles:—

1st. To use baleines whenever the surface of the ground is not much broken, the height of the embankment exceeds 3^{m} 00 (9ft. 10in.), and the cubic amount important.

2nd. To proportion the baleines to the height, and the cubic quantity of the embankments to be made.

3rd. To discharge the wagons without baleines, but with siding places, in the more trifling earthworks, when the height is less than 2 or 3 metres (6 feet 7 inches to 9 feet 10 inches), or if the ground varies much, and occasions numerous cuttings and embankments, the amount of which is inconsiderable.

4th, and lastly. To discharge the wagons without baleines or siding places when it is merely necessary to increase the size of an embankment already made, since this enlargement may be readily made by a long file of wagons tipping at the side.

Comparison of the French barrow with the English, represented in Plate 8.

The barrow being the machine in most frequent use for the transport of earth, many engineers have endeavoured to improve it, by shifting the position of the weight with respect to the wheel, and by increasing the diameter of the latter and lengthening the handles, which modifications have produced but little results; the workmen always prefer the ordinary barrow. That used in France cannot, however, be conveniently used in the formation of earthwork with wagons; and this obstacle not having been foreseen, is so much felt in practice, as to occasion a modification in the mode of opening a cutting, by which the expenses are increased.

It will not, therefore, be uninteresting to consider the construction of barrows requisite to be used in connexion with extensive earthworks, and such as are executed by means of wagons.

The barrow of the shape adopted in fortification, appears to us very convenient for the transport of earth in ordinary cases of earthwork.

Some persons have sought to place the wheel nearer the centre of gravity of the load, in order to ease the man who wheels it. This plan would be advantageous, provided the wheel ran on a plank, perfectly hard, smooth, and horizontal. But under different circumstances—for instance, if the soil yielded to the pressure of the wheel, or a slight obstacle presented itself—it would be stopped, as the man exerts but a weak effort in a horizontal direction, and consequently cannot overcome the difficulty. He prefers, therefore, to have the heaviest part of the load on his arms, and by easing the wheel, it is prevented from sinking in any soft soil on which it may rest, and enabled more easily to surmount the obstacles along an unequal road, such as stones or earth, which may have fallen along its track.

We may add, that as the load is generally conveyed up an incline, the weight on the wheel is still more disadvantageously situated, for we may always notice that the labourer who wheels the barrow, stoops to get the weight on his arms in order to disengage the wheel, and to exert his strength as much as possible in a direction parallel to the plane of the weight.

We may therefore consider the load well placed on the ordinary barrow employed for earthwork, with respect to the wheel, and it does not present inconveniences excepting where used in connexion with wagons.

When earthwork is executed by means of railways, it is usual upon the way

being laid down, to carry the earth to the wagons by means of barrows. It is therefore necessary to empty the barrows directly into the wagons, or the men would have to make an additional cast of the earth. Upon the barrows being loaded, it is quite a matter of indifference as regards expense whether they are shot in the wagon or by the side, if the plane on which they are wheeled is of a convenient height with respect to the first, which may always be insured by arranging a convenient method of opening the work.

The French barrow, however, cannot be discharged without turning it nearly over, which obliges the man to place himself in a suitable position to be able to accomplish this, and on a plane sufficiently large; and it is requisite for the plank placed upon the wagon from which the barrow is discharged, to be very thick, in consequence of its great length; it is also expensive to shift the position, so that, in short, the plan of depositing the earth near the wagon (instead of into it) and loading the same with shovels, is generally preferred. This causes a considerable expense, and occasions the loss of a great part of the advantages of executing earthwork by means of wagons.

The barrow employed in England for earthwork is shown in Plate 8. The portion forming the body is spread open wide, and the sides are very much inclined, so as to leave a slight projection only from the bottom. The centre of gravity of the load is placed in the same relative situation, as respects the wheel and the ends of the handles, as in the French barrow. It therefore results from this arrangement—First, That the centre of gravity of the load is situated much lower in respect to the handles than in the French barrow, which renders it more stable and easier to wheel. Secondly, That the contents may be discharged by inclining the barrow at an angle of 45°, and supporting it constantly on the wheel, without requiring the man to alter his position, or to loose his hold of the handles; so that the workman may be placed on a very narrow plank, and the barrow discharged quickly. The discharge into the wagon is afterwards made with great facility, by placing it upon a single plank, as practised in England upon earthworks; this is impracticable with the French barrow. The capacity of the English barrow is the same as that of the French, but it may generally be loaded more without rendering the labour of wheeling greater, which results from the mode of construction, which we have just described.

The wheel is of the same diameter as the French, but formed of cast iron instead of wood. The nave is terminated by a point on each side, which serves for the axle: the periphery is only 0^{m} 025 (1 inch) in thickness, and is finished

by a rounded surface, while it is flat in the French barrow, and five centimetres (2 inches) wide.

The cast iron wheel belonging to the English barrow can only be run on planks placed on the ground, when it clears away the earth and stones which may lie before it; the wheeling, consequently, is soft and easy. The periphery of the wheel with the French barrow being large and flat, soon collects a layer of earth and stones before it, which opposes its movement, and causes it to jump. It therefore requires great efforts on the part of the workman, and obliges him to diminish his load; we cannot therefore too strongly recommend a trial of the barrow employed in England for this kind of earthwork, which appears to us the only one suitable for those works.

DESCRIPTION OF THE METHOD OF EXECUTING THE EARTHWORK AT THE CUTTING OF "DES OGIERS," UPON THE LILLE RAILWAY ON THE BELGIAN FRONTIER. By M. Brabant.

General Description.

The Ogiers cutting is about 1142 metres 37 long (about 1250 lineal yards), its greatest depth is 12 metres 32 (about 40 feet 5 inches), and its average depth is 7 metres 35 (about 24 feet.) The cubic quantity of earth requisite to be removed in order to execute it with slopes inclined at angles of 45°, intersected by solid earth piers (*banquettes*) 1 metre in width, and situated at distances of 3 metres (3·27 yards) from each other, was 218,000 metres (285,152 cubic yards) but the actual contents amounted to 264,000 metres (345,321 yards), on account of the slopes not having preserved their original position. A large portion was necessarily inclined in the proportion of one and a half at the base to one in height, and the banquettes were widened, which caused an increase in the earth removed of 46,000 cubic metres (60,169 cubic yards). The earth consisted of a clay which readily yielded to the spade, but the sides, when perpendicular, would not stand long without falling, if of great height.

Distribution of the Earth from the Cutting.

The cutting having been situated between two small valleys crossed by the railway, was commenced at either extremity, and the earth carried down both valleys by means of wagons run on iron rails. The centre portion of the cutting was removed in wheelbarrows and taken to spoil on each side, at places which, by virtue of a decree of the prefect, the company were allowed the use of, and which were subsequently surrendered to the proprietors, with an indemnity to the amount of the damages occasioned by the same.

During the course of the year 1842, the amount of work was as follows :—

	FRENCH. Cubic Metres.		ENGLISH. Cubic Yards.
Carried by wagons on temporary lines of rails towards Lille, to the valley of Wasquehal..	91,000	=	(119,031)
Carried by wagons on temporary lines of rails towards the frontier, in the valley of Favreuil	75,000	=	(98,102)
	166,000	=	(217,133)
Carried by wheelbarrows and deposited as spoil on the sides of the cutting	42,000	=	(54,937)
Remaining on the slopes to clear away................	10,000	=	(13,080)
Total cubic contents................	218,000	=	(285,150)

The depth of the cutting being 12 metres, and the soil of such a nature as to slip down when cut to any great height, it was therefore resolved to divide it into three lifts, which were made as nearly as possible of the same depths. Two longitudinal excavations, or gullets, three metres wide, were opened in the first instance, in order to expedite the loading of the wagons, the depth being equal to the lift about to be worked, into which the wagons were readily passed and loaded with earth from each side. The stuff was brought forward by wheelbarrows, or thrown up by shovels along the sides, according to circumstances, and afterwards taken up and thrown into the wagons, or the barrows were wheeled direct to the wagons along planks placed to receive them.

The upper lift being much wider than the others, four gullets were formed along it, while three were made in the second, and two only in the lowest.

Carriage of the Earth.

The wagons employed contained each 1·60 cubic metres (2·09 cubic yards), which is only equal to 1·25 metres (1·63 yards) of earth, measured as it stands in the cutting before digging. The average weight of a cubic metre of earth, measured at the clearance, was 1900 kilogrammes (4189 lbs.), and as each wagon carried 1 metre 25, the weight removed was .... 2375 kilogrammes = (5236 lbs.)

Add the weight of wagons	1200	„	= (2646)
Total....................	3575		(7882)

Upon the wagons being loaded, they were linked in trains of four or five together, and carried an average distance of 1000 metres (1090 yards) to the place of discharge.

At the time of working the upper lift, the wagons descended singly upon an inclined plane of 15 millimetres (1 in 67), which afforded them a greater momentum than was necessary to reach the place of discharge, and to carry them over the small portions of embankment completed, the gradient of which was that of the permanent line. But when the two other lifts were in progress, the gradient of the temporary ways of cutting was not sufficient, and it therefore became necessary to draw the wagons along by the assistance of horses.

The number of horses employed in this work was regulated by the gradients, which varied in the cuttings, but the complete portions were always laid to the same gradients as the permanent line. Two horses were required, near Wasquehal, to draw 5 wagons upon an inclination of 5 millimetres (1 in 200), and towards Roubaix one horse per wagon, to ascend a slope of 2 millimetres and a half (1 in 400).

Description of the Temporary Ways.

In consequence of a deficiency in the supply of rails, the temporary lines were constructed with flat bars of iron, 7 centimetres wide (2·758 inches), and 2 and a half (1·085 inches) thick, placed edgeways on small cast-iron chairs; the latter were fixed upon cross sleepers of white wood, at distances of 0^{m} 9 (0·98 of a yard) apart.

This mode of construction, which was adopted from necessity, answered the purpose, although less advantageous than proper rails, both in respect to speed and expense. The teaming was slower, and the cost of maintenance was greater, since they presented greater resistance to the traction, met more frequently with accidents, and also incurred more expense in materials; but, as there were no rails, and the use of carts was impracticable, no other alternative remained but to resort to some other system of temporary way, and that adopted, notwithstanding its inconveniences, was the best expedient that could be employed.

Discharging the Wagons.

The wagons were discharged upon small moveable scaffolds (baleines) of 12 metres (39 feet 4 inches) long, and six metres (19 feet 8 inches) high, put to-

gether in the most simple manner, and costing only 300 francs each. Two pairs of baleines were constantly at work, one pair at each extremity of the two embankments next the cutting. Twelve men were able to discharge five wagons in six minutes, by means of these scaffolds, and, allowing for time lost, more than twenty wagons were tipped per hour; but a greater number could have been discharged had it been practicable to have conveyed them to the baleines.

Although the scaffolds were only 6 metres (19 feet 8 inches) high, they were found sufficient for all parts of the embankment, notwithstanding it was 10 metres (32 feet 10 inches) high in places, but it became necessary to raise the earth to support them; this, however, did not occasion any additional expense, since the earth was wanted to complete the fillings, and it was merely necessary to apply a portion where the ground required raising, in order to fix the scaffolds at suitable heights.

Progress of the Works.

The removal of earth in the cutting of Ogiers was commenced on the 11th of January, 1842, but the works did not proceed very fast until the early part of the month of March following.

During the months of April and May, 250 wagons generally ran upon each incline, making a total of 500 for the entire cutting; but taking the aggregate of these two months only, the number of wagons amounted to 20,500, being an average of 341 wagons per day, inasmuch as Sundays, festivals, pay days, and rainy weather, together with the numerous contingencies which affect the execution of these works, generally reduce the working days by at least one-third.

It having been required that the railway should be opened for the accommodation of traffic by the 1st of May, 1843, and a free transit secured clear of all obstructions, it was necessary, in order to accomplish this, to finish all the embankments before the close of the year 1842; but the results obtained at this period being considered insufficient to warrant this conclusion, it therefore became imperative that additional means should be adopted. It was determined, under these circumstances, to carry on the works day and night, which was done by working double gangs of men, who were relieved every eight hours.

This new mode of working was put into execution on the 1st of Jnne, and during June, July, August, and September, whilst the weather continued con stantly favourable, 8 or 900 wagons ran regularly per day of 24 hours, but taking into consideration the impediments above enumerated, the average only amounted to 1900 wagons per month, which gives a total of 24,000 cubic

metres of earth (31,392 cubic yards). The men continued working during the nights, until December, but not with the same advantage, as after the month of August the bad weather became a very great obstacle.

The cutting was at length completed, on the 26th of December, both in respect to height and depth, excepting about 10,000 metres (13,080 cubic yards) which remained on the slopes, and was intended to be removed when the proper time arrived for finishing them, as this operation could only be performed during the spring of the year.

During the months of January and February, the weather was constantly bad, and the frost and thaw, rain and snow, having rapidly succeeded each other, considerable slips took place, extending over more than half the entire length of the cutting, and the sides suffered considerably. It was determined, in order to guard against a recurrence of these calamities, to increase the inclination of the slopes of a certain portion where the slips had occurred, which was effected at the rate of a metre and a half of base for one of height; and to increase the dimensions of the banquettes, which were increased to different widths, according to circumstances, some of them extending even to 3 metres (3·27 yards).

These alterations increased the quantities of earth removed by 46,000 cubic metres (60,169 cubic yards), the contents being at first 218,000 metres (285,150 yards), were consequently augmented to 264,000 metres (345,321 yards).

The weather having improved, the works were resumed on the 9th of March, 1843, and the trains were enabled, by the 1st of May, to run along the cutting at great velocity.

On the Causes which Occasioned the Land Slips, and on the Means employed to Prevent their Recurrence.

Having alluded to the slips, it is, perhaps, necessary to give some particulars of the causes which occasioned them, and of the means employed to prevent their recurrence. The soil through which the cutting of Ogiers is made consists of three strata of earth of different qualities, the upper stratum, which is about 3 metres in thickness (9 feet 10 inches), is a brick clay, which stands well enough. The lower stratum is the thickest, although it varies: it consists of a compact blue clay, which retains the water and holds it well.

The soil between these two strata is a clay mixed with a quicksand without any tenacity whatever, from which numerous filtrations oozed, and some small springs; the thickness of this bed was about two metres, (6 feet 6 inches,) and it

was constantly slipping over the lower stratum, whereby the upper one was left without support, and great inconvenience consequently ensued. In order to prevent fresh slips, the inclination of the slope was increased, as already stated, by one and a half of the base to one of height, and the width of the banquettes increased.

It is intended, further, to commence works of consolidation, to consist of stones or fascines fixed upon large banquettes, placed upon the lower or solid stratum, so as to keep the intermediate one in its place, and counteract the effects of the quicksand.

Channels will be formed in the banquettes, at intervals, to drain the water which must necessarily collect, and which will be connected at certain spots, so as to be carried off by the main drains.

Work continued day and night.

Two gangs of men and horses were employed, who were relieved every eight hours, by which the works were continued constantly. The hours of relief were four o'clock in the morning, noon, and eight in the evening, which arrangements were found convenient.

The works were lighted at night by different modes, according to the nature of the various operations.

The line was lighted throughout its entire length by common lanterns, and torches were used for such works which required moveable lights, and fires were used at the places of loading and unloading, burning in a sort of iron pan, which gave a clear flame.

These fires were made of small bundles of the refuse of dried fir, split very fine, and cut into lengths of thirty centimetres (about eleven or twelve inches); a few shavings and old tar-ropes were mixed with them, the whole steeped in a mixture of coal-tar, pitch, and brimstone, in a boiling state.

The following Table exhibits the cost of removing a cubic metre of earth from the cutting of Ogiers to the embankment, according to memoranda taken during the works, the length of the lead being 1000 metres (1093 yards.)

Details of the cost of Digging, Loading, Teaming, and Discharging a Cubic Metre of Earth, the length of lead being equal to 1000 *metres* (1093 *yards*), *with wagons running upon temporary lines of rails, drawn by horses, and the gradients of various inclinations.*

GENERAL PARTICULARS.	Price.		Wear and Tear.	Cost of a cubic metre, getting, loading in wagons, discharging and loading, 1000 metres.	Cost of teaming it an additional 1000 metres.
1st. Tools and Tackle—					
110 wagons, at 450 francs each .	49,500	½	24,750		
800 metres of temporary rails, at 26 francs.	208,000	½	104,000		
24 Temporary switches, &c. at 60 francs	1,440	½	7,200		
Sheds and buildings	3,000	½	1,500		
Six moveable scaffolds (baleines) for unloading, at 300 francs	1,800	½	900		
	263,740		131,870		
Interest at 5 per cent. on 263,740 francs for 1 year			13,187		
Total expenses, fr.			145,057		
Total quantity of earth teamed, being . 166,517 met.					
The cost of a cubic metre of earth consequently was $\frac{145,057}{166,517}=$				0·871	0·029
2ndly. Tools and Tackle—					
As materials, timber, iron, steel, &c. . . . . 0·05; Workmanship and labour . . . . 0·06				0·110	0·005
3rdly. Laying and maintaining way				040	0·002
4thly. Carriage of earth—					
Switchmen, drivers, and other men employed in teaming 0·09; Horses used for draught . . . . 0·19				0·280	0·020
5thly. Digging, loading, and spreading the earth				0·470	,,
6thly. Discharging the wagons				0·260	,,
7thly. Sundry charges				0·100	0·400
Cost per cubic metre in francs				2·131	0·060
Equal to per English yard				(1*s*. 4*d*.)	(·388 of a shilling.)

Table *of the Cost of Labour in forming Embankments, the earth being led by wagons from the cutting Des Ogiers, from January,* 1842, *to November, inclusive.*

	Slope of Wasquehal.		Slope of Roubaix.		Total.
	Day.	Night.	Day.	Night.	
Number of wagons	49,445	23.475.	43,710	16,714	133,344
Quantity teamed, in cubic metres, as per note 1 .	61,806·25	29,343·75	54,637·50	20,892·50	166,680·00
Digging and loading wagons.					
Days' work of the navigators	15,529·10	5,333·40	11,700·90	4,134·90	36,697·70
Amounting to, as per note 2 (in francs)	31,058·20	13,333·50	23,400·60	10,337·25	78,129·55
Actual cost . . . . . . „	0·50	0·45	·43	0·25	Average ·26
Discharging the wagons.					
Days' work of the navigators	8,267·90	3,195·40	6,492·90	2,096·70	20,052·90
Amounting to, as per note 2 (in francs)	16,535·80	7,988·50	12,985·80	5,241·75	42,751·85
Actual cost . . . . . . „	0·27	0·27	0·23	0·25	Average 0·04
Laying and maintenance of the way.					
Days' work of layers	1,549·10	348·40	1,047·40	202·80	3,147·74
Amounting to as per note 3 (in francs)	3,872·75	1,045·20	2,618·50	608·40	8,144·85
Actual cost . . . . . . „	0·06	0·04	0·04	0·03	Average 0·04
Days work of the men employed in teaming the earth.					
Switchmen (in days)	830·10	391·70	844·50	285·10	2,351·40
Conductors (ditto)	611·40	243·80	512·50	162·60	1,530·40
Drivers (ditto)	1,397·50	664·20	1,101·05	410·70	3,573·65
Total	2,839·20	1,299·70	2,458·15	858·40	7,455·45
Amounting as per note 2 (in francs)	5,678·40	3,249·25	4,916·30	2,146·00	15,989·95
Actual cost . . . . . „	0·10	0·11	0·09	0·10	Average 0·09
Artificers employed in the repairs.					
Days' work of carpenters, farriers, & harness-makers	1,947·30	71·70	1,657·90	69·20	3,746·10
Amounting to, as per note 4 (in francs)	5,841·90	250·95	4,973·70	242·20	11,308·75
Actual cost . . . . . . „	0·10	0·02	0·10	0·01	Average 0·06
Days' work of horses for the carriage of earth.					
Days' of horses	2,113·70	1,011·40	2,124·70	818·00	6,067·80
Amounting to, as per note 5 (in francs)	10,568·50	6,068·40	10,623·50	4,908·00	32,168·40
Actual cost . . . . . . „	0·17	·21	0·19	0·23	Average 0·19
Total amount of expenses, (in francs) .	73,555·55	31,736·80	59,518·40	23,483·60	188,294·33
Actual amount of labour, as per note 6, per cubic metre (in francs)	1·20	1·05	1·08	1·11	Average 1·12 (·71 of a shilling.)

	Metre.		Yards.		
Note 1. Cubic contents of wagon	1·25	=	1·635		
	Frs. Cts.				
„ 2. Wages of navigators, per day	2 00	=	1*s.* 8*d.* sterling per day.		
„ per night	2 50	=	2*s.* 1*d.*	„	
„ Average	2 13	=	1*s.* 10*d.*	„	nearly.
„ 3. Wages of layers, per day	2 50	=	2*s.* 1*d.*	„	
„ per night	3 00	=	2*s.* 6*d.*	„	
„ Average	2 58	=	2*s.* 2*d.*	„	nearly.
„ 4. Wages of artificers, per day	3 00	=	2*s.* 6*d.*	„	
„ per night	3 50	=	2*s.* 11*d.*	„	
„ Average	3 02	=	2*s.* 6*d.*	„	and a small fraction.
„ 5. Cost per day	5 00	=	4*s.* 2*d.*	„	
per night	6 00	=	5*s.* 0*d.*	„	
Average	5 31	=	4*s.* 5*d.*	„	

„ 6. The average length of the lead was 1000 French metres, equal to 1093 English yards.

Details of the Expense of conveying Ballasting in Wagons drawn upon a Railway by Locomotives and by Horses.

We stated, when treating upon the construction of a railroad, that a portion of the ballasting requisite for laying the permanent way—viz., about one quarter of it—is usually conveyed to the spot by carts, or by means of wagons run upon temporary ways, and that the remainder ought always to be carried upon one of the permanent lines as soon as completed.

The following is a table* of the expense incurred in the conveyance of ballasting upon a portion of the Versailles railway (left bank) by means of temporary ways and locomotives, the load being taken up a gradient of four millimetres (1 in 250). It is followed by another table, being an estimate of the cost of conveyance supposing that horses had been employed instead of locomotives.

It is easy to calculate the expense of conveyance upon a level, when the cost upon a rise of four millimetres (1 in 250) is known, and by deducting the expense of laying the temporary lines, the cost of transporting it on the permanent line may be ascertained.

* This table was drawn up by M. Brabant.

CONVEYANCE OF BALLAST IN WAGONS PROPELLED BY LOCOMOTIVE ENGINES.

Detail of the Cost of Conveyance of a Cubic Metre of Ballast taken from the Depôt at Bellevue, and conveyed from thence to that at Versailles, being a distance of 4226 *metres* (4621 *yards*). *The quantity conveyed was equal to* 36,767·29 *cubic metres* (*or* 48,092 *cubic yards*).

Materials.	Fr.	Frs.
Wear and tear of wagons, being one quarter more than the sum stated in the list No. 20, $\frac{0{,}173 \times 5}{4} =$		0·216
Laying and maintaining the ways $\frac{1}{4}$ ditto in No. 20, $\frac{0{,}243 + 5}{4} =$		0·304
Carriage of 4,226 metres, upon a gradient of 0·004: A locomotive engine, with 10-inch cylinders, and a driver and stoker, would cost per day of 10 hours, about 91 francs . .	91·00	
It will draw, with a speed of 16,000 metres (10 miles) per hour, a train of 4 wagons, containing 14 cubic metres of ballast, having two paid drivers	6·00	
Together . . .	97·00	
Hence it follows that the carriage of a cubic metre of ballast will cost, due regard being paid to the return-trip, when the wagons are empty, at $\frac{97 \text{ fr. } 00 \times 2 \times 4226}{10 \times 16{,}000 \times 14} =$		0·366
Time lost in loading and unloading, $\frac{1}{60}$ of a day, at 97 francs, making, per metre, $\frac{97 \text{ fr. } 00}{60 \times 4} =$		0·115
486 days' work of horses to draw the train near the locomotive engines, at 6 francs	2916·00	
800 days' work of switchmen and attendants upon the rails, at 2 fr. 25	1800·00	
	4716·00	
Which makes, per cubic metre, $\frac{4716 \text{ fr. } 00}{36{,}767.29} =$		0·131
		1·132
Petty charges, $\frac{1}{20}$		0·057
		1·189

The cost of conveyance of 1 cubic metre a distance of 100 metres, being $\frac{1.189}{42} = 0{\cdot}0283$ francs, equal to 1 cubic yard, conveyed a distance of 100 yards, at ·00164 of a shilling.

CONVEYANCE OF BALLAST IN WAGONS DRAWN BY HORSES.

Details of the cost of Conveyance of a Cubic Metre of Ballast taken from the Depôt at Belle-Vue, and conveyed from thence to that at Versailles, being a distance of 4226 *running metres,* (4621 *running yards*). *The quantity conveyed was equal to* 36,767 *cubic metres* (48,094 *cubic yards.*)

	Frs.	Fr.	
MATERIALS.			120 wagons at 4 metres a day = 480 metres, 25 days at 480 = 12,000. Three months are required to carry 36·767·29. Ten wagons are always supposed to be under repair.
Wear and tear of wagons, 130 wagons valued at 33,800fr. Deterioration taken at one-eighth, will make . . .	4225 00		
Repairing and greasing, one-half . . .	2112 50		
	fr. 6337 50		
The contents to be carried being 36,767·29, the cubic metre will be $\frac{6,336\cdot50}{36,767\cdot29}$=		0·173	
LAYING AND MAINTENANCE OF THE WAY.			The carriage taking place upon the permanent line, this part of the expense is reduced to the cost of keeping it in order.
Laying and maintaining a length of 8552 metres at 1fr.	8552 00		
For switches &c.	400 00		
	8952 00		
Which makes the cubic metre of ballast at $\frac{8,952\cdot00}{36,767\cdot29}$=		0·243	
CONVEYANCE OF 4226 CUBIC METRES UPON A RISE OF 0·004.			
Three horses and a cart costing 18fr. per day of 10 hours, will draw three wagons containing 6 cubic metres, or 25,000 cubic metres per day, which makes the cubic metre cost—due regard being had to the return trip, when these wagons are emptied $\frac{18\text{fr. }00 \times 2 \times 4226}{6 \times 25,000}$=		1·014	
Time lost in loading and unloading $\frac{1}{40}$ of a day at 18fr., which makes $\frac{18\text{fr.}00}{40 \times 6}$=		0·075	
Switchmen and attendants upon rails, five hundred men's days at 2fr. . . . . . . 1,170·00			This part of the expense is susceptible of reduction.
Which makes per cubic metre . . 36,767·29 =		0·032	
		1·537	
Petty charges, $\frac{1}{20}$		0·077	
		1·614	

The cost of conveyance of one cubic metre a distance of 100 metres, being $\frac{1614}{42}$ = 0·0384 fr. (Equal to one cubic yard conveyed a distance of 100 yards at ·0223 of a shilling.)

On the General Method employed of Diminishing the Resistance upon Railway Curves during the execution of Earthwork.

The curves required in the execution of earthwork are numerous, and of various radii. The line of rails often becomes inflected and crooked from being imperfectly maintained, whereby the wagons are thrown off the rails. Different expedients are consequently resorted to in order to rectify this, and to diminish the friction.

The wheels sometimes turn on their axles, and sometimes have moveable axles, but the latter are not able to proceed with much speed without running off the line, and even run off when moving with a moderate velocity.

Wagons with four independent axles are also employed, viz., one for each wheel. The wheels are then supported on the axles, and the axles move in a box. This mode presents the same difficulty as the last, although in a somewhat lesser degree. The "Laiguel" system enables us to diminish the resistance on the curves, but as it is necessary to keep the whole of the wheels to the same radius, and of equal height, it is not always practicable, without great difficulty and very great expense.

The "Arnoux" system is too complicated to be applied to embankments, without undergoing important modifications.

In certain cases where the vehicles are propelled by manual labour, we should recommend a kind of truck, called *chien de mine*, and used in mines.

The *chien de mine* consists of a narrow box, of some depth, supported upon two axles and four wheels. The two forewheels are smaller than the hinder ones. This truck is usually run upon wooden ways formed of two lines of timber, placed only a few centimetres distance from each other.

The timbers may be strengthened by bands of iron, in which case the *chien de mine* would run upon an actual iron railway. In passing along a curve the labourer who propels the *chien de mine* rests upon the hindermost part, and makes it swing slightly upon the hinder axle, so that the weight presses upon the two great wheels only. The load is distributed in such a manner as to favour this motion. By this means, the friction which takes place in turning a curve with ordinary carriages upon axles fixed parallel to each other is avoided. A vertical peg is fixed in the box of the *chien de mine*, and connected with a small horizontal friction roller which runs in a groove between the rails, by which the truck is prevented getting off the line.

The conveyance of earth and materials in the Bois de Boulogne, for the fortifications of Paris, was effected by means of a way consisting of a single rail, which was remarkably well laid down, but we regret we have no description of it.

Lines of this kind consist of a longitudinal beam upon which the rail is fixed at a certain height above the ground ; these beams are supported on posts raised in a solid manner and at regular intervals (see cuts.) The kit which contains the load is supported by means of an iron bar or crook connected with a roller which moves along the rails and corresponds with the centre of gravity of the road and the axis of the railway. These kits acquire an oscillatory motion while they are in motion, which is not without inconvenience.

Fig. 1.

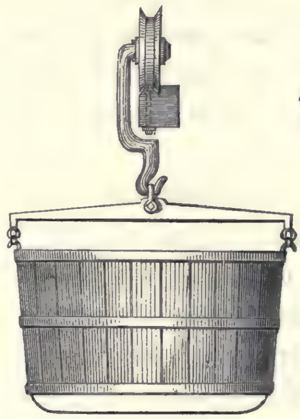
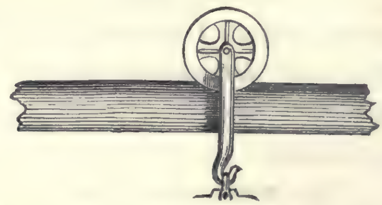


Fig. 2.



One mode which appears very convenient under many circumstances for passing over curves of small radius, and in temporary ways where the loads do not require to be conveyed in large wagons or to great distances, has been applied by M. Serveille, senior, at Mendon, for the working of a quarry, and is described in the bulletin of the Society for Encouragement (year 1842, page 401). It consists in the use of carriages running upon a narrow line of way, (see cuts.) The carriage rests crossways upon the rails, and on points at equal distances from the centre between the two large conical rollers forming the wheels. It becomes displaced laterally at the curves, and rests upon points more or less distant from the base according to the nature of the curve, and in such a manner that the wagons naturally follow the curve of the road. The motion of the wheels is precisely similar to that of two distinct cones rolling upon the way.

Fig. 3.

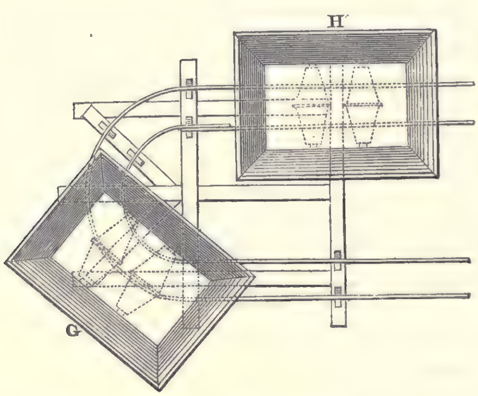


Fig. 4.

The effect produced when M. Serveille's wagons enter a curve is analogous to that which prevails, under the same circumstances, with the common wagons and separate wheels, on the ordinary lines of railway.

But the length of the conical portions being so much greater in M. Serveille's system, the lateral displacement can therefore act upon a greater width, and the wagons, consequently, are enabled to pass over curves of much smaller radius.

Minutes of Specification for the Supplying of Wagons for Earthwork.

ARTICLE FIRST.

The wagons to be built in conformity with the designs and models annexed to the present specification.

The builder is not to modify the forms and dimensions described. Any part formed of inferior dimensions, is to be liable to rejection, and the same with those made of larger proportions.

ARTICLE SECOND.

The iron used in the work to be carefully forged, and of good quality, without flaws, cracks, or other defects. All the ironwork that is broken during the first six months of being in use, shall be replaced at the works, under the direction of the company, and at the expense of the contractor, provided the breakage arises from a defect of quality in the article.

ARTICLE THIRD.

The timber employed for the body and the various parts shall be of the first quality, without defects. It must be properly seasoned, squared, perfectly true on all sides for use, and joined with the greatest care, according to the specification. The edges must also be correctly squared, and the joints free from play.

In case of any part warping from imperfection in quality, or the joints becoming loose during the course of the first six months, they shall be replaced at the shops of the company, and at the expense of the contractor.

The wagons to be formed entirely of oak.

Minutes of Specification for the Supplying of 6000 *Oak Sleepers.*

ARTICLE FIRST.

The sleepers to be 2^{m} 20 (7 feet 3 inches) in length, 0^{m} 32 (0·59 inch) in breadth, and 0^{m} 16 (6 inches) in thickness; the cubical contents of these prescribed dimensions being therefore equal to about 0^{m} 1 (3·53 cubic feet). A difference of $\frac{1}{10}$th over or under each of the above dimensions will be allowed.

ARTICLE SECOND.

If any piece falls short of the *minimum* limit in its dimension, it will be rejected, or if it exceeds the stipulated size, by $\frac{1}{10}$th, the contract price only will be allowed.

ARTICLE THIRD.

The wood to be Champagne oak, of the first quality, and felled at least one year previous. It is to be floated (*flaotté*) timber, and to weigh, at the time of delivery, 60 to 65 livres to the cubic foot (930 kilogrammes to the stere or cubic metre, or 1564 lbs. to the cubic yard).

ARTICLE FOURTH.

The sleepers to be cut up by the saw, and to be squared, so as to leave the smallest quantity of bark and sap-wood possible.

ARTICLE FIFTH.

No piece to have a knot, the centre of which is less than 0^m 30 (11·81 inches) from its extremity.

ARTICLE SIXTH.

Every sleeper to be measured separately, and submitted to a distinct examination.

ARTICLE SEVENTH.

All those having flaws or splits at a greater distance than 0^m 02 (·78 inches) from their extremities will be rejected.

ARTICLE EIGHTH.

The ends of the sleepers to be cut square, without slant or slope.

ARTICLE NINTH.

If more than $\frac{1}{10}$th of the sleepers are rejected, upon any delivery, the contractor shall be bound to pay the company a sum equal to 25 per cent. of the amount delivered, as damages.

ARTICLE TENTH.

The contractor to be bound to convey the wood to the depôts which will be pointed out to him between Paris and Versailles.

ARTICLE ELEVENTH.

Three thousand sleepers to be delivered by the 1st of September, and 3000 by the 1st of October.

ARTICLE TWELFTH.

The price per cubic metre (1·308 cubic yards) to be fixed at , and the tender to state any discount that may be further allowed upon this price.

ARTICLE THIRTEENTH.

Payment will be made as follows: $\frac{4}{5}$ths in ready money, and $\frac{1}{5}$th at six months' date.

ARTICLE FOURTEENTH.

In case of the contractor failing to fulfil any of the clauses of this contract, the company shall be at liberty to annul it, and the contractor shall pay a sum of 2000 francs, by way of damages and compensation to the company.

Minutes of Specification for the Supplying of Cast-iron Chairs.

ARTICLE FIRST.

The form and dimensions of the chairs to correspond exactly with the stamped models transmitted to the contractor.

ARTICLE SECOND.

The chairs to be of two kinds, the *intermediate chair* and the *joint chair*.

The joint chair to form $\frac{1}{4}$th, and the ordinary chairs $\frac{3}{4}$ths of the total number of chairs included in the contract.

ARTICLE THIRD.

The standard weight of the chair must agree precisely with the adopted model to be finally agreed upon by the engineer and the manufacturer before commencing.

A difference of 3 per cent. over or under this weight will be allowed on the delivery. The chairs within these limits will be paid for according to their real weight; but all chairs of less weight will be rejected: those, however, possessing an excess of weight will be accepted, without an extra allowance being made to the contractor.

ARTICLE FOURTH.

The chairs to be of grey cast-iron of the first or second melting. To be tenacious and soft to the file, the grains grey-coloured, compact, and uniform, without any flaws, such as smut, blisters, &c. The positive resistance to be at least 1500 kilogrammes to a square centimetre of section (3307 lbs. to ·155 square

inches). This strength to be proved by decisive experiments made during the course of manufacture, and as often as the engineer may consider necessary.

The manufacturer to be bound to submit the chairs to whatever modes of examination the directors may think proper to adopt.

ARTICLE FIFTH.

The surfaces of the chairs to be smooth and uniform, all the irregularities and seams being levelled by proper tools, and the edges rendered smooth. The bottom face of each chair to be perfectly even, so that there shall not be any vacuity below them, on being fixed to the sleepers supporting the line.

ARTICLE SIXTH.

The contact of the rail with the cheeks or sides of the chair to be perfect throughout, which condition will be strictly insisted upon. One end of a stamped rail will be sent to the manufacturer to guide him in the manufacture. The examination by the engineers to consist in passing an exact model, formed of plate iron, into each chair.

ARTICLE SEVENTH.

The delivery of the chairs to be made at the works once a week, at least. The engineer appointed to receive them shall have the right of trying, or of delegating to others their examination, together with the necessary trials for determining whether the whole of the conditions of the present contract have been properly complied with.

All the expenses connected with the delivery and trials instituted by the engineer, or his delegated agent, to be made at the expense of the contractor. The whole of the chairs accepted are to be stamped.

ARTICLE EIGHTH.

Should any of the chairs become injured during their conveyance, or broken either before or at the time of fixing, they will be rejected, notwithstanding their delivery at the works after being tested. The rejected chairs to be weighed and returned to the contractor at one of the places of delivery, and to be deducted from the amount of his delivery, or he shall replace them if the directors prefer it. The expenses of this final examination is also to be borne by the contractor.

ARTICLE NINTH.

The delivery to be made at spots to be determined by the engineer, and near the workshops or depôts established along the line of railway, provided such parts can be approached by a road passable for loaded wagons.

ARTICLE TENTH.

The whole supply to consist of chairs.

The contractor to deliver and convey the number of chairs comprising his contract, at his own expense and risk, to the places pointed out for the delivery, within the period of . The directors shall, however, be at liberty to defer receiving the chairs if they think proper; in which case, the contractor is to pile them in order, in regular prisms, in a warehouse to be supplied by the directors at the iron-works, so that they may be readily counted.

ARTICLE ELEVENTH.

The amount of the contract to be paid to the contractor, upon the production of the receipt of the provisional reception at the works, excepting 1-4th, which will be retained to cover the expense of conveyance of the rejected chairs, on fixing, and as security. The sum retained will be reduced to 1-10th, at one month after the delivery of the chairs.

The chairs, when thus received at the factory, and piled up in the company's warehouse, will be considered to form part of the contract. It is, moreover, understood that the contractor shall, conformably to Articles 8 and 9, transport these chairs to the places appointed for the delivery, where they shall be subjected to further tests.

ARTICLE TWELFTH.

The manufacturer to guarantee the chairs for the first year, and when in use on the temporary line. Every chair which becomes injured during this prescribed term, by any cause whatever, unless it be proved to have resulted from a violent shock, shall be replaced at the expense of the contractor; the remaining tenth due to the contractor will not be paid until after the expiration of the period of guarantee.

ARTICLE THIRTEENTH.

In case of the contractor not having completed his contract at the period stated in the present specification, $\frac{1}{10}$th of the total amount of the chairs not delivered at the periods assigned shall be deducted from the sum due to the contractor as damages.

ARTICLE FOURTEENTH.

Further, the contractor is to be subjected to the clauses and general conditions drawn up on the 25th of August, 1833, by M. the Director-General of Bridges, Highways, and Mines, for all works connected with Bridges and Roads.

ARTICLE FIFTEENTH.

No party will be allowed to tender who is not the proprietor or manager of a foundry.

Minutes of Specification for the Supplying of 14,000 *Wrought Iron Bolts.*

ARTICLE FIRST.

The bolts to be one hundred and eighty millimetres ($0{\cdot}180^{mm} = {\cdot}708$ inches) in length, exclusive of the head, which is to be nineteen millimetres ($0{\cdot}019^{mm} =$ 748 inches) in thickness; the head to be squared and flattened, and of the thickness of eighteen millimetres ($0{\cdot}018^{mm} = 0{\cdot}78$ inch), and to be exactly similar in shape to the given model.

The weight to be with a limit of 1—10th if below this, but if over this, the extra weight will not be paid, thus a thousand bolts should weigh or at least

In each of which cases the exact weight will be paid, for if they weigh less they will be rejected, and if they weigh more the stipulated weight only will be paid for.

ARTICLE SECOND.

The bolts to be of Roche iron, soft, and not liable to fracture when cold.

ARTICLE THIRD.

The proving to be made on 1-10th of the supply, which will consist in striking the bolt when cold with a hammer, so as to form it to an angle of about 45 degrees, and then to bend it straight again. If 1-10th of the bolts thus tried break, the whole will be rejected.

ARTICLE FOURTH.

The bolts broken either in the trial or during their use, to be replaced by the contractor, the turning up of the head of the bolt to be a sufficient defect for this step. This guarantee to continue for one year from the day of their delivery.

ARTICLE FIFTH.

7000 bolts to be delivered by the 1st October next, the remaining 7000 on the 15th October, and forwarded to the depots pointed out to the contractor between Paris and Versailles.

Minutes of the Government Specification for the Supplying of Rails.

ARTICLE FIRST.

The rails to be of the exact shape of the stamped model to be remitted to the manufacturer. The cross section to be exactly similar throughout the entire length of the rails, more especially at the extremities, which are to be carefully protected from any compression or alteration at the time of sawing.

ARTICLE SECOND.

The standard length of the rails to be 4^{m} 50 (14 feet 9 inches) for the greater facility of manufacture. One rail in twenty will be admitted at a length of 3^{m} 75 (12 feet 3 inches), provided these shorter rails arise during the manufacture of those required of the standard length, and which have been clipped in consequence of flaws at their extremities.

The weight of the rail to be determined by the model delivered to the manufacturer, and which will be proved at the first delivery. An allowance of two per cent. over or under will be made on this weight, provided the whole supply does not differ from the standard weight by more than $\frac{1}{100}$th. The rails to be paid for according to the actual weight within the limits of allowance. If below this limit, they will be rejected; they will be accepted if above it, but the contractor will lose the extra sum arising from any excess above the standard weight.

ARTICLE THIRD.

The iron employed in the manufacture of the rails to be of two qualities; the body of the rails may be of coarse puddled iron, but the top and bottom faces to be each formed of a single piece of iron previously forged. For this purpose the *bundles*, subsequently drawn into rails, are to be formed of not more than two-thirds of coarse puddled iron, with one-third, at the least, of iron previously forged.

ARTICLE FOURTH.

The workmanship of the rails to be perfect in every respect. All those which may be badly welded or formed with flaws, or indented on either face, will be rejected.

ARTICLE FIFTH.

The whole of the rails to be cut at the two ends by a saw, or by some other efficient apparatus, to be agreed upon by the Directors. All excrescences to be

carefully removed. The planes of the sections to be perfectly square with the axis of the rails. The allowance on the fixed lengths never to exceed a millimetre and a half, (0.059 of an inch.) Every rail which is ordered to be cut at a different length from the standard, to be paid for at the rate of five per cent. above the contract price.

ARTICLE SIXTH.

The rails to be dressed on both sides with the greatest care, their surfaces being made smooth and uniform, and they must fit into the chairs, employed to support the rails, with the greatest accuracy; the chairs will, therefore, be sent to the manufacturer to enable him to fit them together.

The rails to be capable of bearing, and to be submitted to the following proof, which is to be made peremptorily with any portion of the rails which the engineer may select.

The rails are to be rested upon two supports of 0^m 08 (3·14 inches) in size, and at a distance of 1^m 12 (3 feet 8 inches) from each other (*centre to centre*), when each rail is to be capable of supporting a weight of 8000 kilogrammes (about 8 tons), in the middle of this bearing, without undergoing any perceptible deflection.

ARTICLE SEVENTH.

The provisional delivery of the rails at the works to be made at least once a week. The engineer appointed to receive the rails, and to examine them, shall have the right of trying, or of delegating to others, the necessary trials for determining whether the whole of the conditions of the present contract have been properly complied with; more especially that regulating the mode of manufacture, described in Article 3. All expenses connected with the delivery, and the trials instituted by the engineer or his delegated agent, to be made at the expense of the contractor. The whole of the rails accepted to be stamped.

ARTICLE EIGHTH.

Notwithstanding the delivery of the rails at the works, if, upon further examination, any imperfection should be discovered, even after being placed on their supports, they shall be put aside and submitted to the test of the engineer-in-chief, who shall have the right of rejecting and deducting them from the amount of the contract; and, upon their being weighed, they shall be placed at the disposal of the contractor, at one of the places of delivery.

The expense of this final examination is also to be borne by the contractor.

ARTICLE NINTH.

The delivery to be made at spots to be determined by the engineer, and near the workshops or depôts established along the line of railway, provided such parts can be approached by a road passable for loaded wagons.

ARTICLE TENTH.

The whole supply to consist of rails. The contractor to deliver and convey the amount of rails comprising his contract, at his own expense and risk, to the places pointed out for the delivery, within the period of .

The directors shall, however, be at liberty to defer receiving the rails, if they think proper; in which case the contractor is to pile them carefully in regular prisms, in a warehouse pointed out by the directors at the works, so that they may be readily counted.

ARTICLE ELEVENTH.

The amount of the contract shall be paid to the contractor upon the production of the receipt of their provisional reception at the works, excepting one-fourth, which will be retained to cover the expense of conveyance of the rejected rails, and for security. The sum retained will be reduced to 1-10th at one month after the delivery of the rails.

The rails, when thus received at the factory, and piled in the company's warehouse, will be considered to form part of the contract. It is, moreover, understood that the contractor shall, conformably to Articles 8 and 9, transport these rails to the places appointed for the delivery, where they shall be subjected to further tests.

ARTICLE TWELFTH.

The manufacturer to guarantee the rails for the first year, and when in use on the temporary lines. It is to be understood that the guarantee shall apply to any imperfection in the workmanship, which may not be perceived at the time of delivery. Every rail that becomes injured during this prescribed term, by any cause whatever, unless it be proved to have resulted from a violent shock, shall be replaced at the expense of the contractor. The remaining tenth, due to the contractor, will not be paid until after the expiration of the period of guarantee.

ARTICLE THIRTEENTH.

In case of the contractor not having completed his contract at the period stated in the present specification, 1-10th of the total amount of the rails not

delivered at the period above assigned, shall be deducted from the sum due to the contractor, as damages.

ARTICLE FOURTEENTH.

Further, the contractor is to be subject to the clauses and general conditions drawn up on the 25th of August, 1833, by M. the Director-General of Bridges, Highways, and Mines, for all works relating to Bridges and Roads.

Specification for the manufacture of Rails for the Railway from Paris to Rouen.

ARTICLE FIRST.

This clause is similar to that of the Government Specification for the supply of rails, page 177.

ARTICLE SECOND.

The standard length of the rails to be 4 metres, 80 centimetres (15 feet 8·98 inches.)

One rail in twenty will be accepted at a length of 3^{m} 60 (11 feet, 9·73 inches.) One rail in twenty will be allowed of a longer or shorter length than 4^{m} 80 (15 feet, 8·98 inches.) All the other rails to be exactly this length, and in no case to vary from it more than one millimetre and a half, (0·059 inches.)

The contractor is to inform the company of the exact length of each rail at the time of their delivery, in order that the rails may be classed separately.

The weight of the rail to be 35 kilogs. (71 lbs. per yard) with the same limits to variations described in page 177 of the Government Specification.

ARTICLE THIRD.

This clause is similar to that at page 177, with this difference only, that the bundles drawn out for the rails are to consist of 3-5ths puddled iron, and 2-5ths forged iron, instead of 2-3rds and 1-3rd.

ARTICLES FOURTH AND FIFTH.

Similar stipulations will be found in Articles 4, 5, and 6 of the Government Specification, page 177. The employment of the lever screw instead of the hammer in the (cold) straightening is required of the manufacturer. The rails must be capable of bearing the following proof. Upon being placed freely on two supports of 0^{m} 05 (1·95 inches) wide, and at a distance of 1^{m} 20 (3 feet, 11·24 inches,) from centre to centre; each rail must support a weight of 8000 kilogs., (about 8 tons,) in the middle of this bearing, without sustaining any permanent alteration.

ARTICLE SIXTH.

This is similar to Article 7, at page 178.

ARTICLES EIGHTH, NINTH, TENTH, ELEVENTH, AND TWELFTH.

These are similar to Articles 8, 9, 10, 11, 12, and 13, at pages 178 and 179.

On the Specifications employed in Belgium.

The specifications employed in Belgium do not differ essentially from the preceding, except that they stipulate for a trial by *shock* in the following manner: —Each rail of 27 kilos (54 lbs. per yard) is required to be placed on supports at a distance of one metre (3 feet 3.27 inches) from each other, and is to be capable of bearing, when cold, a deflection equal to 1-10th of the distance between the supports. This is to be produced by the fall of a rammer of 200 kilos. (nearly 1-5th of a ton) dropt from a height of four metres, (13 feet 1·48 inches.) N.B.—The extent of surface of the rammer was not stated in the Specification which we examined.

The specification for the Railway from Roanne to Andresien stipulates for the distance and the shock in the following terms:—

Rails weighing 13 kilos. (25 lbs. per yard), similar to the old rails of the line from St. Stevens to Lyons, and resting on supports placed at distances of ninety centimetres (3 feet), are to receive the shock of a rammer of 2000 kilos' weight (2 tons), with a surface of four square decimetres (62 square inches) dropt from a height of 60 centimetres, (1 foot 11·62 inches.) The rail must not bend more than 12 centimetres (4·71 inches) from the effects of the blow, and it must be capable of being re-bent, whilst cold, to its original shape.

Minutes of Specification for the supply of Iron Pins for the Railway from Amiens to Boulogne.

ARTICLE FIRST.

The shape of the whole of the pins to be like the pattern which shall be forwarded to the manufacturer by the engineer-in-chief of the company.

ARTICLE SECOND.

The *normal* weight of the bolts to conform strictly to the model determined previously between the engineer and the manufacturer. An allowance will be

made, on delivery of the pins, of 3 per cent. more or less than this weight; they will be paid for, within this limit, by their real weight; if below this weight, they will be rejected; but they will be accepted if they exceed it, provided they are conformable with this specification in other respects; the additional weight will not, however, be allowed the manufacturer.

ARTICLE THIRD.

The company reserves the right of inspecting the manufacture in the workshops of the manufacturer.

ARTICLE FOURTH.

The pins to be of iron of good quality—soft, but not fragile; the head to be made out of the solid piece, and not joined on it.

ARTICLE FIFTH.

Trial to be made peremptorily by the engineer at the time of delivery on some portion of the supply delivered. This trial to consist of driving the pin half-way home into an oak block, and striking it laterally on its upper extremity, so as to make it form an angle of 45 degrees with the vertical. The pin is then to be withdrawn, and redressed cold, without exhibiting any fracture.

ARTICLE SIXTH.

Besides the pins which are rejected on their reception at the store-yards, all that are found inadmissible, either by deficiency or excess of weight, as well as those which break under the hammers of the workmen, will be rejected, and are to be replaced by the manufacturer.

ARTICLE SEVENTH.

The contract to comprise 250,000 pins.

ARTICLE EIGHTH.

The delivery to be made at the magazines of the company, at the places directed by the chief engineer, on the 15th of July and the 15th September, so that the supply shall be completed at the last date.

ARTICLE NINTH.

The contractor to be paid for the contract in proportion to the supply, to be

proved by the receipts, excepting a drawback of one-tenth of the amount, which is not to be paid for until after the bolts are employed.

ARTICLE TENTH.

In case the manufacturer should not fulfil his contract, and the deliveries are not made at the times stated, the engineer-in-chief is authorized, without being under the necessity of giving any formal process, to complete the number of pins forming the contract at the expense of the manufacturer, by any means in his power.

ARTICLE ELEVENTH.

In case of difficulties and disputes on any point, and of whatever nature, relative to the contract, the parties engage, by these presents, to refer to M. ——, chief engineer of the company, residing at ——. The arbitrator to decide finally, as sole arbitrator, without appeal or trial; and, moreover, as a friendly umpire, to dispense with all forms and the delay of processes. The contractor hereby agrees to the said arbitration, the company having informed him that M. ——, the chief engineer of the company, is appointed by them to receive the above-mentioned supplies.

Examined in duplicate, by the undersigned, who is appointed to superintend the present contract, this day, 3rd February, 1846.

On the Preparation of Wood.

The attention of the engineers of railways has been for some time directed to the processes employed, or proposed, for the preservation of wooden sleepers, and as we have collected some information on the efficacy of the same, we will present a statement of it to our readers.

M. Payen, member of the Academy of Sciences, in the course of his lectures, delivered at the Museum of Arts and Manufactures, states the causes of alteration in wood to be as follow:—

1st. The solubility of the animal matters which it contains.

2nd. The weak cohesion of its parts.

3rd. Their four-fold composition. We know that the more elements a body contains in its composition, the sooner it decomposes.

4th. The oxygen of the air, heat, and humidity.

5th. The azotic matter which is contained in wood.

6th. The insects, such as ants and teredos.

The woodwork of the ports of Rochefort and Rochelle have suffered considerably from the action of these insects.

The following have been employed or proposed for the preservation of wood:—

1st. Creosote.

2nd. Tannin.

3rd. The bichlorate of mercury, or corrosive sublimate.

4th. Arsenic acid.

5th. The pyroligneous acid and pitch.

6th. Marine glue.

7th. Marine salt.

8th. Pyrolignites of lead and iron.

9th. Sulphate of protoxide of iron.

10th. Sulphate of copper.

11th. Sulphate and chlorate of zinc.

12th. The usual acids and acid salts.

13th. The alkalies.

14th. Fat of all kinds.

15th. Resins.

The creosote is the most efficacious, but is too expensive.

Pyroligneous acid and pitch contain a great quantity of creosote, and act in the same manner, but with less energy.

Marine glue may be ranged among the reactives whose use appears to be most efficacious.

Fat generally, and the resins especially, produce an excellent effect, but are too expensive.

M. Bourdon, of Dunkerque, states that he has used tannin with advantage for the preservation of wood, yet leather prepared with tannin is not protected from the effects of moisture?

We are doubtful respecting tannin for the preservation of railway sleepers, since it has not been tried sufficiently long, or upon a scale to establish the several experiments made to test its efficacy, and we therefore cannot recommend it.

The corrosive sublimate appears to be the best of all the reactives. It has been used with advantage on the greater part of the English railways. Although soluble in itself, yet it becomes insoluble when it is combined with the albumen of woody substances. It is, moreover, an active poison, and destroys insects, but it has, unfortunately, become very high in price.

Arsenic acid is dangerous to the workmen.

Marine salt preserves the woodwork of mines perfectly, but is expensive, and it absorbs water in very damp situations.

The sulphate of the protoxide of iron attacks the fibres of the wood, and separates them. It is the same with all the acid salts, and still more so with acids.

The alkalies dissolve the azotic particles well, but they also separate the fibres, and moreover form slimy solutions which obstruct the drainage.

The chlorides of lime and magnesia may be employed with advantage to preserve elastic timber, but they are deliquescent.

Borates and phosphates of ammonia are only used to preserve the wood from fire.

The sulphate of copper appears to be a more convenient reactive than any. It forms an insoluble compound in the wood, and is neither deliquescent nor expensive. As this salt is not volatile, the health of the workmen is not endangered. It is not acid, like the sulphate of the protoxide of iron, and therefore does not attack the fibres of the wood.

The sulphate of copper is also a destructive poison to insects.

The properties of the sulphate of zinc are very similar to those of the sulphate of copper, but the latter is a more scarce article in trade.

The operation of penetrating the wood by reactives is effected by different systems. Sometimes the reactives are introduced by natural agents, such as the process of vegetation, and sometimes by mechanical means, or by simple immersion.

It cannot be introduced by the power of vegetation only, or be made to act on the trees while standing, or on those which are fresh cut down. The mode of operation is described in the review of the course of organic chemistry by M. Payen, published by MM. Knab and Leblanc, a work to which we refer our readers.

The process of M. Payen, which consists of introducing the liquid by pressures, is more simple; it is also reviewed in the course of this professor.

Lastly, there is a third process of impregnating wood with the reactives of

M. Breant, which consists in placing each piece in a cast iron cylinder, and exhausting this cylinder, which disengages the air from the pores of the wood, and then forcing the reactive liquid into the wood by means of a pump.

Wood subjected to this mode of treatment is penetrated more effectually by the liquid than in either of the two first methods; but the operation is very expensive.

The following Tables, taken from M. Payen's course, show the prime cost of preserving trunks of wood, of 6 or 7 metres long (19 feet 8 inch., or 23 feet,) and 32 centimetres (12 inches) diameter.

Pine and fir, 120 to 130 litres (4·2 to 4·5 cubic feet), oak poplar, 100 to 110 litres, (3·5 to 3·8 cubic feet.)

	frs.	cts.	£	s.	d.
Pyro-lignite of iron of the forests of Choisy, 100 kilog. (220 lbs.) to 5°, at 1 fr. 50 cts. per 100 kilog. (220 lbs.)	1	50	(0	1	3)
Pyro-lignite of solid lead, 5 kilog. (11 lbs.) at 78 frs. per 100 kilog. (220 lbs.)	3	50	(0	2	11)
Pyro-ligneous acid, 40 kilog. (88 lbs.) to 7° at 10 frs. per 100 kilog. (220 lbs.)	4		(0	3	4)
Tar water rendered 25 kilog. (55 lbs.) at 12 frs. per 100 kilog. (220 lbs.)	3		(0	2	6)
Bichloride of mercury, 0·8009 kilog. (1½ lbs.) at 13 frs. the kilog. (2·205 lbs.)	10		(0	8	4)
Iode, 0.0505 (0·111 lbs.) at 25 frs. the kilog.	4		(0	3	4)
Chlorydrique acid, 1 litre (61·028 cubic inch.), alcohol ½ litre (30·514 cubic inch.) at 25 frs. per kilog. (2·205 lbs.).	4		(0	3	4)
Sulphate of zinc, 5 kilog. (11 lbs.)		(variable.)			
Sulphate of iron, 5 kilog. (11 lbs.) × 50 litres (1·7 cubic feet) of oil	90		(3	15	0)
Crude rosin of the lands, 100 kilog. (220 lbs.) at 10 frs. per kilog. (2·205 lbs.)	10		(0	8	4)

Details relating to the cost of the Turntables supplied from the works at Fourchambault.

	fr.	£	s.	d.
Contract price of each turn-plate	2594	(103	15	0)

Details of Weight.

	kilog.	
CAST IRON—		
Upper plate	2074	
Circumscribing crown-piece	455	
Bottom plate	124	
12 friction rollers	338	
Iron collar	10	
Socket	9	
	3010=	(6,637 lbs.)
WROUGHT IRON—		
2 rings	178	
2 rails	376	
12 bolts for the friction rollers	123	
1 iron shaft	31	
2 hoops, or tires	7	
22 tie bolts	31·50	
22 rail bolts	20	
4 socket bolts	7	
	773·50 =	(1705·7 lbs.)
Copper for socket	1·00	
RECAPITULATION—		
Cast iron	3010	
Wrought iron	773·60	
Copper	1	
	3784·60 =	(8345 lbs.)
Cost of model	450 fr. =	(£ 18 0 0)

Estimate of a Turntable for the Versailles Railway (left bank), similar to those on the London and Birmingham Railway.

CAST IRON.

	Cubic metres.	
Platform, outer circle, section 0·0115 long, 12 metres	0·1380	
4 girders carrying the rails, section 0·012 long, 16 m.	0·1920	
2 ditto on the cross, 0·015 and 4 metres	0·0600	
Centre	0·0300	
	0·4200	(2·11 cubic ft.)

	Kilog.	
The 0·42 cubic metre of cast iron weighs, at the rate of 7210 kilog. to a cubic metre	3000	
Outer ring, section 0·0046 × 13 metres 0·0598, at 7210 kilog. the metre cube	432	
Plate for the friction-rollers, section, 0·0057 × 12 metres, 0·0684	492	
Socket	60	
8 friction-rollers at 20 kilog.	160	
Weight of iron castings . .	4144	(9137 lbs.)

WROUGHT IRON.

4 lines of rails, length together 16 metres, section 0·0048, } 0·07680 metres at 7800 kilog. per cubic metre	599	
4 inclined planes at the crossing of the rails . . .	15	
52 bolts for the rails at 2 kilog.	104	
8 bolts for the friction-rollers	88	
2 iron rings joining the bolts of the friction-rollers (11·90 each, or 2330 taken together) 2330 × 0·0008, 0·01904.	148	
1 connecting ring for the friction-rollers.	10	
28 bolts at 2 kilog. 50	70	
1 iron shaft steeled	20	
1 brass socket.		
1 iron angular ring		
Total length, 13 metres at 7 kilog. the running metre	91	
Total weight of wrought iron . . .	1145	(2524 lbs.)

SUMMARY.

	frs.	cts.
4144 kilog. of cast iron at 60 cents	2486	40
1145 kilog. of wrought iron at 1 fr. 30 cents . .	1448	50
To the manufacture . .	3974	90

	frcs.	cts.	
Brought forward	3974	90	
The cost of the model of a turn-table and its appendages would amount to 1400 (£56), which should be divided amongst the number of turn-tables required. If 7 are ordered, 1-7th of 1400 francs must be added	200		
	4174	90	(£167 0 0)

This amount may, however, be reduced by 1-5th or even 1-4th.

Details of the Expense of two Timber Turn-tables, on the Railway from Paris to Versailles (left bank).

WROUGHT IRON.

	kilog.
8 cross bars weighing	57·50
8 squares	240
2 rings	160
16 shafts for the friction rollers	31
48 bolts	57·20
2 pivots with steeled points	45
32 double pins for friction rollers	6
2 screws for the pivots	3
2 shields	1·50
8 bolts	8
10 bolts	2·50
32 double pins	6
8 rollers, 25 kilogs. each	200
Total	817·70 = (1803 lbs.)

	frs.	cts.	£. s. d.
817·70 kilog., at 62 frs. per 100 kilog.	506	95	(20 5 9½)

CAST IRON.

	kilog.
16 irons, or supports of the friction-rollers	448
16 friction-rollers	160
2 square plates for pivots	15·20
2 socket plates	40
Total	663·20 = (1462 lbs.)

	frs.	cts.	£ s. d.
663·20 kilog. at 55 frs. per 100 kilog.	364	80	= (14 11 0)

Steel.

	kilog.				
2 pivots in steeled iron	2				
2 lintels	5				
Total	7				
	frs.	cts.		s.	d.
7 kilog. at 2 fr. 10 cts. per kilog	14	70	=	(11	9)

Timber.

	fr.	cts.		£	s.	d.
10 steres of oak at 82 frs. per stere	820	00				
1848 of deal at 75 frs.	138	50				
	958	50	=	(38	6	9)

WORKMANSHIP.

Wrought Iron.

	fr.	cts.		£	s.	d.
(By the piece.) 8 cross bars at 3 frs. each	24					
8 squares, at 2 frs. 50 cts.	20					
2 rings at 10 frs. each	20					
16 shafts for the friction-rollers at 1 fr.	16					
48 bolts at 30 cts.	9	60				
2 do. of steeled iron, 40 kilog. at 50 cts.	20					
2 lintels of 5 kilog. each, at 50 cts.	2	50				
32 double pins at 1 fr.	32					
2 screws for pivot of 2 kilog., at 40 cts.		80				
8 plugs at 25 cts.	2					
10 bolts at 20 cts.	3	20				
8 mouldings at 30 cts.	2	40				
32 double pins for the friction-rollers	32					
(Day-work.) 2 shields 8 bolts (6 hours)	4	50				
8 slips (1 day)	8	25				
Total	197	25	=	(7	18	0)

FITTINGS.

	frs.	cts.	
(8 days.) 8 cast box irons at 4 frs. 50 cts.	36		
16 friction-rollers at 1 fr.	16		
(2 days.) 2 socket plates	9		
(1 day.) 1 square plate for pivot	4	50	
(1 day.) 2 pivots with steel points	4	50	
(1 day.) 2 lintels	4	50	
(6 days.) 32 double pins	27		
(2 days.) 8 panels in plates	9		
(6 days.) 32 double pins	27		
			£ s. d.
Total	137	50	=(5 10 0)

TURNING.

	frs.	
16 friction-rollers, by agreement	40	
16 beams, do. 1 franc 25 cts.	20	
(1 day.) 2 socket plates	10	
(2½ days.) 2 pivots, steeled points	25	
(1 day.) 2 lintels	10	
		£ s. d.
Total	105	(4 4 2)

TAPPING.

	frs.	cts.	
48 bolts, at 20 cents.	9	60	
(1 hour.) 2 pivots	3	25	
(3 hours.) 2 screws for pivots		85	
(6 hours.) 8 bolts	1	70	
16 bolts at 10 cts.	1	60	
			s. d.
Total	17	00	(0 14 0)

BORING.

	frs.	cts.	
8 cross bars at 95 cts. (task work)	7	60	
8 squares	15		
(2½ days.) 2 rings	7	50	
(2½ days.) 16 friction-rollers	25		
(6 hours.) 8 mouldings	1	60	
8 slips	8		
			£ s. d.
Total	64	70	(2 12 0)

Carpenters' Work.

	frs.	cts.	
60 days at 4 frs.	240		
(23 days.) Saws at 7 frs. 75 cts.	178	25	£ s. d.
Total	418	25	(16 14 7)
Coal	38	75	(1 11 0)

Recapitulation.

Raw materials, including coal	1883	90	
Workmanship	938	70	
Making together	2822	60	
Sundry expenses, 20 per cent.	564	52	£ s. d.
Total	3387	12	(135 9 7)

Or, 1693 frs. 55 cts. (£67 14*s.* 9*d.*) per turn-table.

Statement of the Expense of a Crossing-place and Switches, forming a complete change of Line on the Versailles Railway (*left bank*), *See Plate* 16.

1st.—The Crossing-place.

	frs.	cts.
From seven-tenths to eight-tenths of a cubic metre of rough oak, at 80 francs per stere, the timber being supposed to be of the first quality, say eight-tenths of a cubic metre	64	00
To carpenters, sawing it out and fitting, due regard being paid to the great precision with which this work is required to be done (laying not included)	80	00
26 bolts for securing the cross-pieces, weighing 26 kilogrammes, at 1 fr. per kilogramme	26	00
8 bolts of 00·27^{m} (1 inch) in diameter, for a similar purpose, weighing together 14 kilogrammes, at 1 fr. per kilogramme	14	00

Weight of Iron forming the Crossing.

	kilog.
2 curved rails	274
2 guard rails	274
2 pieces forming the point	94
	642
Loss in forging, 1-20th	32
	674

	kilog.	frs.	cts.	frs.	cts.
Brought forward				184	00
674 kilogrammes, at 40 francs the 100 kilogramme		269	60		
Forging the 6 pieces		20	00		
Coal 225 hecto, or 200 kilogrammes, at 55 francs per 1000 kilogrammes		11	00		
Sundry expenses, 1-5th		61	00		
				361	60
3 bolts for joining the joints, weighing 4 kilogrammes, cost making				4	45
(See details in the following page.)					
Marking the chairs				4	25
Total, exclusive of chairs				554	30
For the Switches.					
1m 70 cents. of timber, comprising the sleepers N, O, P, (see Plate 16), at the rate of 80 francs per cubic metre				136	00
The fixed points which the moveable switches or guard-rails rest against, weighing	152·00				
Waste 1-20th	76·0				
	159 60				
159·60 kilogrammes, at 40 francs the 100 kilogrammes		63	85		
Forging		6	00		
Coal 0·75 hecto, weighing 60 kilogrammes, at 55 francs per 1000 kilogrammes		3	30		
Sundry expenses, 1-5th		14	65		
				87	80
2 moveable switches forming guard-rails, weighing	304·00				
6 wedges	3·66				
1 connecting rod	35·20				
2 supporting bolts	9·00				
1 cast-iron eccentric	27·66				
Iron	13·00				
Brass	1·00				
	393·52				
393·52 kilogrammes, at 0.75 the kilogramme				295	15
Total of the switches, exclusive of chairs and laying down, fr.				518	95

Recapitulation.

	frs.	cts.			
For the crossing-places, exclusive of chairs and laying down	554	30			
For the switches, say, in round numbers	600				
The chairs* for the crossings and the switches, being a total of 450 kilogrammes, at the rate of 25 francs per 100 kilogrammes	112	00			
Laying the crossings and switches	120	00	£	s.	d.
Total expense of laying down change of line complete,	1386	30	(55	9	0)

Details of the cost of Bolts for fastening the Crossing-points.

	frs.	cts.				
Materials for 3 bolts, at 0·40 cts. the kilogramme .	1	60				
Waste, 1-10th		16				
			1	76		
Forging at the rate of 35 cts. each			1	05		
Tapping at the rate of 30 cts. each				90		
			3	71		
Sundry expenses				74	s.	d.
			4	45	(3	8)

* These chairs, requiring particular models, cost rather more than the ordinary ones.

Details of Prices relative to the Construction of the Line, Changing Places, and Turn-tables, on the Railway from Lille to the Belgian Frontier.

Number and subject of the following details.	Details of Tackle and Workmanship.	Price.		Observations.
		As calculated.	In Practice.	
		Francs.	Francs.	
No. 1. The making of a temporary line with rails of 30 kilog. (61 lbs. per yard) to the running metre, supported on oak sleepers, at distances of 1·125 metres, (3 feet 8·27 inch.) apart, the ground being supposed to be levelled.	Loading, unloading, and conveying, by barrows, from the depôt to the wagons, and from the place of unloading to the spot where required	0·100		
	Transport by wagons of the transverse sleepers, rails, and wooden wedges, to an average distance of 1500 metres (about 1600 yards); two horses and carter, paid 14 francs per day, conveyed the materials required for the construction of 120 metres (about 130 yards) of way per day, which gives per metre .	0·117		
	Notching the sleepers and bolting the chairs at 15 cents. per sleeper, gives per metre $\frac{0\cdot15}{1\cdot125}$	0·133		
	Construction—A gang, composed of a foreman, at a salary of four francs for a day of ten hours; under foreman, at three francs; and six men, at two francs fifty cents; making together an expense of 22 francs, will prepare and lay down 70 metres (229 feet 7 inches) of single line, which gives per metre	0·314		
	Expense of tools and waste being . .	0·060		
	Price per running metre . . } Equal to 7d. per running yard.	0·730	0·75	
No. 2. Construction of a permanent line, with rails and sleepers as above, the soil being supposed to be level.	Loading, unloading, and conveying, by barrows, conveying, notching, and bolting the chairs, as before in No. 1 . .	0·350		
	Construction—A party composed of and paid as before, laid down and prepared 50 metres of way (about 54 yards) per day of ten hours, which gives per running metre	0·440		
	Expense of tools and waste	0·079		
	Price per running metre . . } Equal to 8¼d. per running yard.	0·869	0·90	
	This price does not include the maintenance of the way, which is generally very expensive at first, but which varies considerably according to the season, the weather, the nature of the ground, the greater or less importance of the embankments, and the rate of speed of the traffic. In rather unfavourable circumstances, the maintenance of the line may amount to 40 cents. per running metre, or 3¾d. per running yard, during the first month.			

Number and subject of the following details.	Details of Tackle and Workmanship.	Price.			Observations.
		As calculated.		In Practice.	
		Francs.		Francs.	
No. 3. Construction of a temporary change of line, consisting of a crossing and switch rails, with an eccentric.	A party, composed of and paid as before, laid down a change of line in eight hours, which will amount to . . .	17·60			Thirty francs was paid for a change of temporary line on the line of the Versailles, left bank.
	Fittings	3·40			
	Expense of tools and waste	3·00			
	Cost of a change of line	24·00		24	The change of permanent line, the construction of which is estimated, consists of a Belgian iron crossing plate, switch rails on Stephenson's plan, with counter weights. The execution of the permanent change of line on the Versailles (left bank) cost 120 francs.
No. 4. Construction of a change of permanent line, composed of a crossing and switch rails, with an eccentric.	A party, composed of and paid as before, laid down a change of line, in two days, which gives for the cost of the same .	44·00			
	Carpenter, two days' work, at four francs	8·00			
	Mounter, one day, at six francs . . .	6·00			
	Ditto two days, for adjusting at four francs	8·00			
	Various works	16·00			
	Expenses of tools and waste	8·00			
		90·00		90 (£3. 12s.)	
	The sums stated in Nos. 3 and 4 do not include any more than the laying down of the parts mentioned. The laying down the line between the crossing points and the switch rails was paid for separate, and at higher rates than those given in Nos. 1 and 2, by 50 per cent. at least, and it may be much greater when the levelling presents difficulties, on account of the additional time required.				
No. 5. Construction of the foundation for a turn-table of 4·50 metres in diameter (14 feet 9 inches) for locomotives made on the system employed on the Belgian lines.	EARTHWORK AND MASONRY.				
	25 cubic metres (882·73 cubic feet) of earth excavated and conveyed a distance of 200 metres (about 218 yards), at 1 fr.	25·00			
	15 cubic metres (529·8 cubic feet) of common masonry, at 18 fr.	270·00	341·00		
	0·25 metre (8·4 cubic feet) of cut stone masonry, at 150 fr.	37·50			
	0·25 cubic metres of mortar, at 34 fr. .	8·50			
	ACCESSORIES.				
	1·40 cubic metres (49·3 cubic feet) of oak for sleepers, at 120 francs per cubic metre	168·00	188.00		
	44 lbs. of lead for soldering, at 1 fr. (labour included)	20·00			
	RAISING, ADJUSTING, AND FIXING.				
	Mounter, 1 day, at 6 fr.	6·00			
	2 days' adjusting, at 4 fr.	8·00			
	Carpenter, 2 days' work, at 4 fr. . . .	8·00	46·00		
	Stone-cutter, 2 days' work, at 4 fr. . .	8·00			
	Labourer, 8 days' work, at 2 fr. . . .	16·00			
	Extra labour	......	15·00		
	Expense of tools and waste	......	10·00		
	Price of a platform	......	600·00	600· (£24.)	

No. and Subject of Detail.	Details of Tackle and Workmanship.	Price. As calculated.		Price. In Practice.	Observations.
		Francs.			
No. 6. Construction of the foundation for a turn-table of 3·40 metres in diameter (11 feet 1·85 inch) for wagons on the same system as last.	EMBANKMENT AND MASONRY.				
	20 cubic metres (706 cubic feet) of earth excavated and conveyed a distance of 200 metres (218 yards) at 1 fr. . . .	20·00	272·80		
	12 cubic metres (433 cubic feet) of common masonry, at 18 fr.	216·00			
	0·20 cubic metre (7·06 cubic feet) of cut stone-masonry, at 150 fr.	30·00			
	0·20 cubic metres of mortar, at 34 fr. . .	6·80			
	ACCESSORIES.				
	0·90 cubic metre (31·79 cubic feet) of oak for sleepers, at 120 fr. the cube metre .	108·00	123·00		
	15 kilogrammes (33 lbs.) of lead for soldering, at 1 fr. (labour included) . .	15·00			
	RAISING, ADJUSTING, AND FIXING.				
	Mounter, 1 day mounting, at 6 fr. . .	6·00	64·00		
	.... 2 days' adjusting, at 4 fr. . .	8·00			
	Carpenter, 2 days, at 4 fr.	8·00			
	Stone-cutter, 2 days, at 4 fr.	8·00			
	Labourer, 6 days, at 2 fr.	12·00			
	Extra labour	14·00			
	Expense of tools and waste	8·00			
	Price of foundation for a platform . .	......	460·00	460· (£18 4s.)	

The quantity of masonry and earthwork required in the foundation of turn-tables is very variable, and depends entirely on the nature of the soil where they are situated.

The amount in this case corresponds to a *minimum*, as the earth on which they rest is supposed to be solid; but if they were placed upon earth of less resistance, as upon embankments newly made, and of great height, the expenses for the foundations would be necessarily much increased.

When the foundations are secure, the cut stone, wood, and workmanship, always remain the same.

The friction-rollers run upon a cast-iron circular plate, fixed upon oak sleepers, which are cramped to the masonry. Other sleepers, fixed upon these, are employed to carry another cast-iron plate, placed round the platform, and level with the planking, for the purpose of preserving it from the ballasting.

There is merely a single cut stone placed in the middle, to receive the pivot, which it encases, being maintained by bolts; the whole is cramped in lead.

List of the Tools required by a Gang of Layers, with their Prices.

	Frs.	Cts.
1 Wooden rammer, bound with iron	8	0
1 Set of levels, composed of five—two red, two black, and one white	15	0
4 Pickets, shod to receive the levels	16	0
2 Wooden rules of 4^{m} 50 (14 feet 9 inches) . . .	10	0
1 Wooden lever, shod	30	0
1 Iron crowbar, with claws, for dressing the rails, weighing 41 kilogrammes (90 lbs.)	49	20
1 Iron crowbar for dressing the way, weighing 20 kilog. (44 lbs.)	18	0
1 Iron hammer, for driving the wooden wedges in the chairs, weighing 4 kil. (9 lbs.)	7	85
1 Iron guage for setting out the width of the ways .	3	0
1 Hand hammer		
1 Auger, of 18 to 20 millimetres (0·708 inches to 0·787 inches) in size	2	0
1 Tool marker	3	0
	165	05 or £6 12*s.* 0*d.*

*On Changing-Places and Crossings.**

Changing-places, with moveable switches, are best suited for lines where the trains constantly run in the same direction. We believe in fact that they possess an important property, and one which is peculiar to them (when properly laid), viz. that of enabling the train, on arriving at the switch, to place the rails in the proper position, if they should not by any accident have been previously arranged so.

We will call the end forming the centre of rotation, the *heel* of the switch, and the tapering end the *point.*

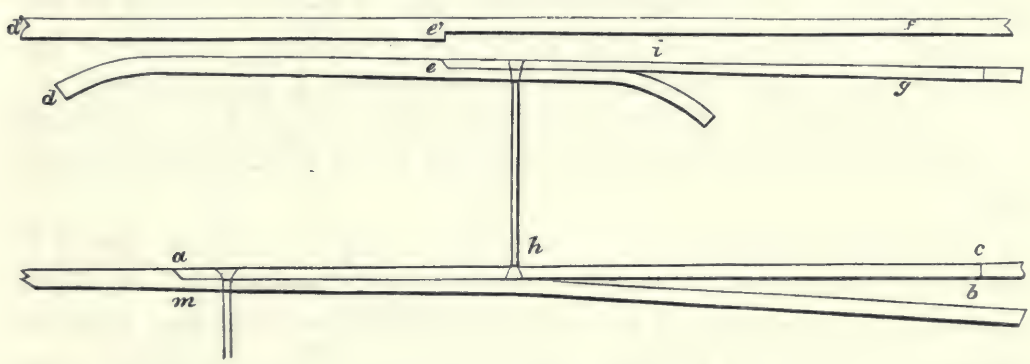
The switch rails are kept constantly open in one direction, on the right hand line, which is the most used, since this generally forms the trunk line for both ways, by means of a counterpoise acting on the axis of the lever used by

* This note was drawn up by M. E. Meyer, formerly a pupil of the Central School of Arts and Manufacture, and employed under the direction of M. Eugene Flachat, in the construction of the S. Germains Atmospheric Railway.

the switchmen. We may, however, perceive from what has transpired, that the counterpoise is not required in the exceptional case, or when the train proceeds from the point towards the heel of the switch: it is necessary, in fact, for the switchman to lift up the counterpoise, in order to open the oblique way, at the time of a train passing.

An accident which occurred on the Orleans line, proves this to be a serious inconvenience: we ought not, however, to employ a catch for the purpose of guarding against it, since the counterpoise would then be perfectly useless. It is merely necessary, in order to ameliorate this movement in the way as much as possible to dispose the levers in a convenient position, so that the slightest force shall be sufficient for them.

The switch rail *a c* (in the cut) which serves for the oblique way, is the only one that produces a change in the direction of the train, and consequently the only one necessary to be formed of great length; being made 4^{m} 50 (14 feet 9 inches) or upwards. The second *e g* which forms a part of the right way, is generally 3^{m} to 3^{m} 50 (9 feet 9 inches to 11 feet 6 inches.)



The switch rails are connected together—1st. At their heels, by means of a strong sleeper, the centre of rotation being always placed perpendicular to the axis of the crossing.—2ndly. By an iron bar, either round or square, near the point of the switch *e g*. It is considered requisite to provide means of lengthening or shortening this bar, in order to adjust the relative position of the two switch rails, as may be necessary in the laying down, or at any subsequent period, although this is not indispensable to the perfect working of the rails. It appears to us more important to make the connecting rod of two or three pieces jointed together, by which some play is afforded to the relative movement of the two switch rails.

In order to lay down a change of way with moveable switches, geometrically,

we require to determine, first, the angle of deviation *b a c*, which is regulated by the use for which the changing-place is intended, the situation and the velocity of the trains upon reaching it, the distance between the axles, &c. These regulate, at the same time, the length *a c*, for *b c* is a quantity nearly constant upon all lines, being made as small as possible. It is determined by the width of the rail, and the grooves requisite for the passage of the flanges of the wheels. We shall represent this angle by its trigonometrical tangent *b c* / *a c;* taking, for example, $b\ c = 105^{mm}$ (4 inches); $a\ c, = 4^{m}\ 50$ (14 feet 9 inches), we have for the value of their *relation* about $1^{m}\ 43$ (4 feet 8 inches.) The following numbers give the results for the different switches recently constructed:—

Mr. Stephenson's switch	1 / 41
Switch on the Orleans Railway	1 / 40
„ on the Rouen ditto	1 / 43
„ on the St. Germains ditto . . .	1 / 51

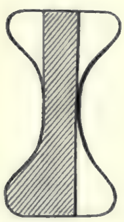
This angle may be diminished in certain cases. The above figures always give the inclination of one way to the other after it branches off, and do not really show the deviation to be given to the line of the train, unless one of the two ways continues along the line of the common trunk; if, on the contrary, one deviates to the right and the other to the left of the terminal line, it is evident that the deviation would be, in reality, one-half for each; but this very rarely occurs.

The points of the switches not being square with each other, the part *d' e'* serves for the two ways, so that *D' e'* and *a b* are not parallel; and the slight deviation traced by the rail *a b* in one direction, diminishes in the same degree as the deviation produced in an opposite direction by *a c*. This extra width between the two rails of the same line is limited by the distance between the wheels and the play arising from the wear of the peripheries of the flanges, and it ought not to exceed 50 millimetres (2 inches) in ordinary cases.

According to the figure represented by the last Cut, the line *d e g* is broken; where it is run over by the carriages, the point *e* is protected from the shock of the wheels both by the increase of distance at this point and by the switch *a c*, which being then separated from the line *a b*, serves as a guard-rail to it. The point *a* is protected by the guard-rail fixed at the opposite side, and which ought always to be prolonged to a certain distance to the left of the point *d*.

The interior line *a c* is straight, the thickness of the rail determines the point *h*, at the parting of which, and up to the point *a*, the rail and the switch

are cut in the same line. This line is composed of the tangent *m h*, and of an arc of a circle *a m* of 15 millimetres' (half an inch) diameter, having its centre on *a c*. The angles of the point are afterwards reduced, and *m h* and *h c* are joined together by an arc of a circle of large radius.



The diagram bears reference to the upper portion of the switch only, the champignon remains at the lower part of the switch-rail, and upon the side opposite the rail, the switch consequently has the annexed section, which gives it great stability.

Any strain is also prevented, by making the switch abut against the rail, as before stated, and from *h* and *c* against the brackets. The point is furnished with a layer of steel for a length of 20 to 30 centimetres (8 to 12 inches), and of the thickness of about a centimetre, (39th of an inch.)

Finally, in order that the switch should maintain the proper thickness of the rail, the plane of the chair on which it rests is placed from 1 to 2 millimetres (·039 inch to ·078 inch) lower than that supporting the rail, the latter consequently supports the greatest part of the weight.

It is necessary that the surface on which the switch slides should be horizontal, and the switch perfectly vertical, which is as much to facilitate its movements as to prevent the necessity for varying its relative height along the rest of the way, also to secure an equal distribution of the weight on all the chairs more readily, and prevent flexion; this also allows (by reason of the inclined position of the rails) of 5 to 6 millimetres (0·19 inch to 0·23 inch) more iron being left on the lower champignon than it could have had if the switch had been placed on a plane parallel to that of the rail.

The switches are moved by a system of levers, with counterpoises and rods. The axes of the levers ought to be at least 1^{m} 20 (3ft. 11in.) from the exterior rail of the road. The standards which support them are bolted on a piece of wood, firmly set in the ballasting, and secured to the roadway-sleepers. The whole of this apparatus is enclosed in cast iron, for the purpose of preservation.

We may state, in reference to the rotation of the switches, that the system of depending upon the flexion of the pieces and the play of the adjustments is abandoned, and a hinge is fitted to the vertical axle, which attaches the switch either to the rail or the chair, or lastly, with the guard-rail.

In the first, and also in the third instance, the foot of the chair requires to be prolonged beneath the hinge, in order to support the heel of the switch.

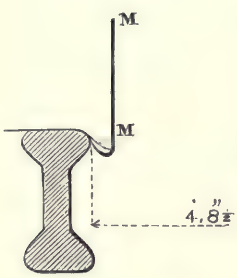
The guard-rail operates by forcing the flange of the wheel as close as possible to the rail, to which it is nearest, and diverting it from the opposite one. It is therefore necessary, when the right way is open, that the switch, *c a*, should be situated at a sufficient distance from the rail, in order not to come in contact with the wheels arriving in the direction of the deviation. (See cut.)

Fig. 1.

When the *materiel* are new and perfect, the flanges of a pair of wheels attached to the same axle are both at the same instant very close to the rails, and it is not necessary to leave any more room than sufficient for the thickness of the flange and the switch, except at the points *a á*. Afterwards, when the peripheries and the rails become worn, the flanges get further from the rails, as the distance between the rails remains as originally.

If, for instance, we take the sides of the figure shown in cut 2, and find that after a certain period of service the thickness of the flange should be reduced to 20 millimetres (0·78in.), the interior plane of the wheel M M may become a distance of $2 \times (45 - 0) + 20 = 70$ millimetres ($2\frac{3}{4}$in.) from the rails. The thickness of the point of the switch being 15^{mm} (half an inch), the minimum of its course will be $70 + 15 = 85^{mm}$ (3in.), which being a *minimum*, it is often necessary to alter the eccentrics and cranked axles employed in transmitting the movement, from neglecting this precaution, which is further applicable to every kind of switch.

Fig. 2.



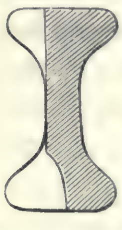
The point *e* is not exposed to the same danger of a shock, provided it lodges properly on the notch in the guard-rail. The course of the switch *g* ought to be such, that on slightly raising the iron point on the angle *i*, the wheels shall pass readily over the rail *d' f* of the oblique way. This may further lead to an increase of the course of the longer switch.

All that has been said on the plan and on the details of construction of *a c*, is applicable to *e g*.

The guard-rail ought to extend 45 or 50^{mm} ($1\frac{3}{4}$ to 2in.) from the rail at the point *d*, in order to protect the point *a* effectually. When the oblique way, *a c*, is open, its position at *e* is determined by the course of the switch, the line

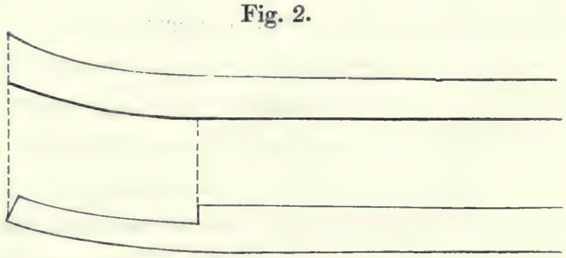
of which, $e\,g$, fixes equally the direction of the guard-rail in the second part of its length. Upon leaving the point e, the section should present the following form, which is necessary in order to receive the switch.

Fig. 1.



Independent of the horizontal curvature which is always adopted at the extremities of the guard-rail, it is necessary to curve them vertically sufficient to allow of their being driven into the ballasting, which is accomplished by raising one portion of the height of the rail in a heated state, and beating down the other. This arrangement facilitates the passage of the ropes when a train is towed along on one way by an engine proceeding along another parallel line.

Fig. 2.



It is by no means indispensably necessary to place the guard-rail on a higher level than the chairs of the rail. The common mode of fastening is evidently inadmissible when a switch moves at the side of the rail; it is consequently replaced by a bolt of 25^{mm} ($\frac{7}{8}$in.), with a very long screw. Even then it is necessary, in important cases, and the distance of the switch permits, to adopt a mode of fastening by which the rail shall be boxed firmly upon each side, without any manner of fastening; in which case it is necessary to introduce the chairs at the end of the rail, and to slip them along until they reach their places.

This plan of securing the entire fastening with a bolt upon one or two chairs near the heel of the switch, may be strengthened by cast iron supports placed within the rail, like brackets, which will counteract any tendency to derangement. These supports should rise to at least one-half of the height of the switch.

The distance between the upper plane of the rail and the top of the chair ought to be at least 45^{mm} ($1\frac{3}{4}$in.) Whenever a less height is adopted, it will be found insufficient with the fastenings now in use.

It is necessary to increase the number of the cross sleepers at the changing places, as they should never exceed 90^{cm} (3ft.) from centre to centre.

It is generally found necessary to introduce the rails sideways into the chairs, and to turn them up properly afterwards, by which the rails describe a fourth part of a revolution upon their axes. It would, perhaps, be found advan-

tageous to remedy this mode of fitting, by leaving a greater distance between the cheeks of the chairs, and employing thicker wedges; the rails could then be dropped vertically into the chairs, or the latter taken up, when they are fixed to the sleepers by a simple vertical movement. This mode becomes imperatively necessary whenever the rail is disposed along a curve, or in replacing a broken one, since the men cannot manage to lay a curved rail in its place by any other plan without losing a great deal of time, and devoting much labour to it. The cast iron chairs and the rail are necessarily grazed against each other.

Although the distance between the switch and the fixed point depends on the radius of the curve joining them, still it is necessary to make proper arrangements respecting the joints of the rails, in order to employ as little cutting and soldering as possible. It is therefore necessary—

1st. To calculate the distance according to the curve intended to be adopted corresponding to the angle of crossing required.

2nd. To complete this distance (taking care to exceed it a trifle) by disposing the rails in a suitable manner, and upon which the exact length will depend. The rails should present the least possible amount of soldering, also of cutting, but more particularly of the former.

3rd. To join the two lines of direction by means of an arc of a circle, of which it is necessary we should find the radius, or, if necessary, by a right line and an arc of a circle. The radius of this arc should not be less than that originally pointed out.

TABLE.

Radius of Curve.		CALCULATED DISTANCES.							
		Distance between the moveable point and the fixed.				Distance between the moveable point and the point where the intermediate space has attained 1·80.			
Metres.	Yards.	Metres.	Yds.	Ft.	In.	Metres.	Yds.	Ft.	In.
150	(164)	20·73	(22	2	0)	44·36	(48	1	6)
200	(219)	23·95	(26	0	7)	51·26	(56	0	0)
300	(328)	29·35	(32	0	3)	62·84	(68	2	2)
400	(438)	33·91	(37	0	3)	72·41	(79	0	7)

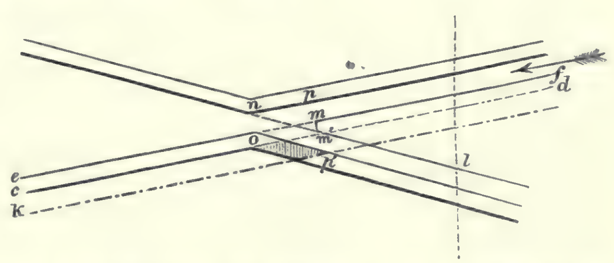
The numbers are found on the supposition that the moveable point represents the chord of a portion of the arc tangential to the ordinary way, while the deviation is much more sudden than that which would be given by the ordinate to the tangent of the connecting curve. It is necessary to take this deviation into account in the third operation above stated.

As the two rails forming the right line, in changing places, diverge from each other as they proceed, therefore where the line is straight they afterwards converge towards each other. If it is curved, the *interior* rail must be placed on a circle of greater radius than the exterior. The bearings between about eight or ten of the sleepers following the switches are too great in both cases. The radius of the curve of union is limited to a *minima* by the resistance which it opposes to traction, and to a *maxima* by the correlative diminution of the angle of crossing, a diminution which increases the break in the continuity which takes place at this point. A curve of 200 metres (219 yards) appears to be the best suited for crossings at the stations, which corresponds to a fixed point whose angle equals 0·12 per metre.

It is necessary to increase the radius of the curve considerably in changing places, which are traversed at great speed, and to place a switch or moveable guard-rail at the crossing.

The crossing should be disposed on the supposition of its being traversed most frequently from heel to point, like the switch. The extremity of the fixed point at *m* should be 15^{mm} (half an inch) thick. (See cut.)

The space *n o* forms the limit to which the rails approach before they turn off to form guard rails, and it ought to be no larger than sufficient to admit of a passage for the flanges of the wheels, in order to reduce the break in the continuity *o m* as much as possible. It is made equal to 4^{cm} ($1\frac{1}{2}$ inch). There are also 4^{cm} ($1\frac{1}{2}$ inch) from *a n* to *p*, and from *m′* in *p′*, according to the geometrical construction of the diagram.



Supposing a wheel passing in the direction of the turn, and supporting itself by the internal angle formed in its periphery, (next the flange) against the interior edge of the rail *f e*. It is necessary that the wheel should have acquired a hold on the guard-rail, upon its arriving at *m*, in order to prevent slipping, for should this occur, even to a trifling extent, the wheel will not rise again

without producing a shock at p'. This may evidently be effected by the method just described, since $m\,p'$ should barely exceed 5 centimetres (2 inches), which is the distance that we have already allowed for the switches.

The fixed point is protected the same as the switches—1st. By placing a chair at the extremity. 2ndly. By furnishing the same with a layer of steel, with rounded edges, 25 to 30 cents. long (10 to 12 inches.) 3rdly. By making the guard-rails one to two millimetres (0·039 to 0·078 inches) higher than $o\,p$, $o\,p'$* Further, a guard-rail supported by the three sleepers, corresponding to the three chairs $n\,m\,l$, ought to be placed between the outer rail, a little more room being given at the two extremities than is left in the middle. If the crossing should happen to be traversed in a direction opposite to the bend, it would be a good plan to prolong the guard-rail one or two metres, (3 feet 3 inches or 6 feet 6 inches) to the left of the chair $n\,o$. The guard-rails $n\,p$, $o\,p$, appear to be sufficiently prolonged, when they are supported by the two chairs m. They are also further secured by being incorporated with the rails placed to the left of the chair o.

The point a is called the *mathematical point.* The intersection of the lines which determine it are 15 millimetres (half an inch) apart on one side $m\,m'$, and 40 millimetres ($1\frac{1}{2}$ inches) on the other $n\,o$. The length $a\,m + a\,n$, would be the same if m and n were at the same side of the point a. Moreover, it is easy to perceive that they would form one length equal to the sum of $a\,m + a\,n$, by starting from the summit of the angle a, and touching the points on each side, which would give a distance of 40 + 15=55 millimetres (2·16 inches.) If, therefore, the angle of the fixed point is 0·11 per metre, the distance $m\,o$ will be $=\frac{0{\cdot}055}{0{\cdot}11}=0^{m}\ 50$ (20 inches), and for a point of 0·15 $m\,o=\frac{0{\cdot}055}{0{\cdot}15}=0^{m}\ 3666$ (14 inches.) We conceive that the fixed point will be tried in proportion as it becomes isolated. If the action to which it is subjected is on the contrary distributed over some length of the way, the point will preserve its level and wear much longer, the passage of the crossing will also be imperceptible, provided the line is well constructed. It is therefore of the highest importance to secure the whole of these rails and guard-rails particularly firmly, in order to obtain the

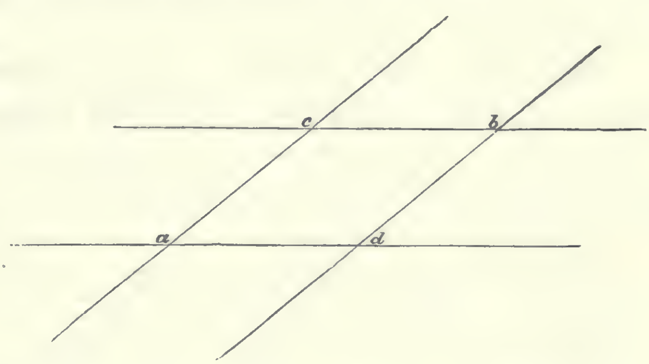
* It has been considered necessary, for reasons entirely secondary, to increase this elevation to above 12 millimetres (0·47 inches) for example at the chair placed at l. But the exterior line, forming the periphery of the flange, being developed on $k\,l$, consequently sustains the whole weight of the carriage for a moment, and therefore becomes greatly altered, after a time, from its action on the guard-rail along this portion, until the latter obtains the proper level, and the weight is distributed over a suitable surface.

proper position, and to maintain it securely. One of the most efficacious means of consolidating the fixed point, and more particularly of preserving it from displacement, is to make it of great length, since it then forms a triangle, whose base maintains the vertical position of the whole. The lengths in the latest examples that we are aware of, are three or four metres (9 feet 9 inches or 13 feet) for the smallest branch, and 3^{m} 50 to 4^{m} 50 (11 feet 5 inches to 14 feet 9 inches) for the largest.

The two rails forming the point were with few exceptions welded until a very recent period. This having been found difficult to accomplish with rails of great length, another contrivance is at present substituted, which does not require the rails to be heated. It can also be executed with much greater precision, and affords the requisite rigidity, without presenting any difficulties.

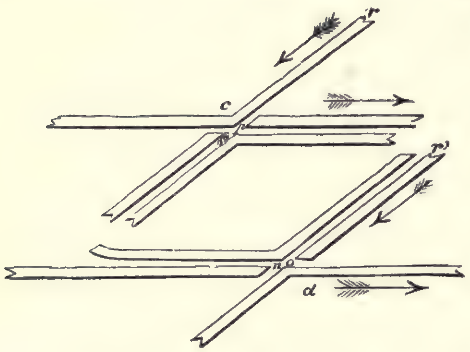
The point is formed of one rail for a length of about 45 to 50 centimetres, (1 foot, 6 inches to 1 foot 8 inches) from its extremity, the champignon being cut away so as to expose the vertical face on which the second rail is required to be applied. In order to unite these rails together properly, and in the most solid manner, it is advisable to maintain them at first by means of two or three screws, then to pierce other holes through the two pieces which are intended to form one, and to introduce proper screw-bolts into the same, screwing them into the screw-holes as tightly as possible, and removing any salient parts afterwards. It therefore follows that if it were necessary to replace a point, this connexion could not be undone without removing all the chairs supporting one of the two branches, which is an inconvenience. It is, however, unavoidable, as a means of ensuring the requisite solidity.

The lines frequently *pass across each other* at the stations, and at the branching off places, as shown in the diagram. There are four points of crossing in this instance, the rails meet at *a* and *b* without interruption, and form acute angles, and those at *c* and *d*, the angles of which are obtuse, are exactly opposite.



Each extremity of the rails at *m*, *n*, *o*, *p*, in the following cut, may be considered as so many fixed points of one piece, to which all that has been before stated is applicable.

Various means are employed to prevent the trains getting off the rails at these crossings; that adopted on the Orleans line is the most simple, and appears to answer the purpose at the stations. It consists in applying two angular guard-rails along each of the two fixed points, *m*, *n*, *o*, *p*, carrying them as near as possible to the angles *c* and *d*—*that is to say*, within 40 to 50 millimetres (1½ inch to 2 inches) of them.



These points, which may be described as *opposed to the direction of the trains*, are always subjected to the greatest wear; therefore, when the direction of the traffic is specifically determined upon each way, we are consequently made acquainted with the points which will be most exposed, and which ought to be fixed with the greatest security. The usual precautions consist in simply elongating the guard-rail placed along the sides of the points for supporting them, and which precedes them in the direction of the trains; since therefore, the two lines are to be traversed in the direction of the bends, it is necessary to make the two branches of the curved guard rail near the angle *d* of great length.

The points are protected more effectually by making them moveable, but this method should always be reserved for occasions where great speed is employed, as it is much more expensive. There is a good combination of these methods at Colombes, upon the crossings of the return line of St. Germains with the departure line of the Paris to Rouen.

The system employed on the St. Germains railway, in front of the workshops of Batignolles, and at the *branching-off place* leading to the Carrière de la Folie, near Nanterre, is less expensive, and although, upon the whole, satisfactory, still it participates slightly in the inconveniences before enumerated in reference to the switches formed with moveable rails.

When the angle of crossing approaches 90°, it presents an inconvenience which does not occur in the various cases already examined, since the breaks in the continuity of the rails cannot be any longer supported by guard-rails; the wheels are consequently unsupported when they pass across them. It occurs, for example, with turn-tables furnished with two lines of rails fixed at right angles, and the inconvenience is increased by the difficulty of taking up and restoring the parts in the present construction of the turn-tables, as they become affected by the shocks.

A shock inevitably occurs every time the wheels pass over these rails, since they are some centimetres apart. Although the effects are only slight at first, they soon increase, until, by degrees, as the points wear, the level of the rails becomes slightly sunk at these parts.

Where crossings at right angles cannot be avoided, we recommend that the *break* in of the continuity of the rails—i. e., the *joint*—should be formed as close as possible, and that those portions of the rails which form it should be furnished with steel. Means ought also to be provided for taking up and replacing these portions of the rails readily, whenever it may be required.

Agreement for the Construction of Guard-rails for the Versailles Railway, (left bank.)

The undersigned (*Reviron*) master carpenter, of Versailles, engages, by these presents, to execute the following works for the Versailles Railway Company, (left bank), subject to the annexed conditions:

1st. Four Guard Rails, each of 13^{m} 50 (44 feet 3 inches) length, for the level crossing of the road, No. 40, at Bellevue.

2nd. Four Guard Rails, each of 9^{m} (29 feet 6 inches) length, &c., for the level crossing of the rue des Potagers at Bellevue.

3rd. Four Guard Rails, of 9^{m} (29 feet 6 inches) length each, for the level crossing of the rue Velizy, at Bellevue.

4th. Four Guard Rails, of 9^{m} (29 feet 6 inches) length each, for the level crossing of the rue Mélanie, at Bellevue.

5th. Four Guard Rails, of 9^{m} (29 feet 6 inches) length each, for the level crossing of the rue du Cerf, at Bellevue

6th. Four Guard Rails, of 9^{m} (29 feet 6 inches) length each, for the level crossing of the rue Emile, at Bellevue.

7th. Four Guard Rails, of 23^{m} 30 (76 feet 5 inches) length each, for the level crossing of the avenue de Viroflay.

8th. Four Guard Rails, of 14^{m} 40 (47 feet 2 inches) length each, for the level crossing of the rue de la Patte d'Oie, at Versailles.

9th. The continuation of the platforms on the two sides of the *station* at Versailles, in connexion with those constructed by M. A——, to the point of the bridge in the rue de Limoges.

10th. The wooden curbs round the well-holes of the turn-tables. These works to be executed in conformity with the designs of M. B———.

The timber for the Guard Rails, supports for the Platforms and Curbs to be of oak. The flooring of the platform to be of fir.

The timber to be of the best quality, sound, without splits, shakes, bad knots, rottenness or defects, and also free from sap.

The price is hereby agreed to be 100 francs per cubic metre for the rails at Bellevue; 95 francs for the rails at Viroflay, and for the platforms of Patte d'Oie; and lastly, 130 francs for the curbs. The timber to be measured when the work is finished, and fixed in its place without any extra quantities being allowed.

In consideration of the above prices, the undersigned engages to deliver the timber at the works, and to add the iron-work required in fixing the same, and to indemnify the Company of all charges for the works above stated.

In the event of the Company supplying the timber, it shall be allowed for at the rate of 75 francs.

The undersigned engages to deliver and fix in their place the guard-rails for Bellevue by the 31st of this month. Those for the avenue of Viroflay and the Patte d'Oie by the 5th of August, and the platforms by the 10th of August next. It is understood that all the several works shall be entirely completed by the time above specified. In case of non-completion of all or any of the works by such period, the undersigned will submit to a deduction of 2 francs for each day's delay, to be deducted from the amount of the contract.

The works to be paid for within a fortnight after their completion.

Versailles, 1840.

Details of the Cost of a Gate, 9 metres (29 feet 6 inches) wide, and formed with four Openings.

CARPENTER, &c.

		frs.	cts.
4 oak posts of 3^m 40 long, at 25 francs		100	
8 transverse pieces of oak, 1^m 60 long 4 uprights of oak, 2^m 18 long 4 uprights of oak, 1^m 25 long	26^m 50 at 14 frs.	106	
52 cross pieces of oak, 4^m 50 long, 54^m at 2 francs		108	
4 inner cross pieces of 4^m 50 long 8 uprights in oak, 1^m 25 long	28^m at 70 cents	19	60
166 bars of oak, 1^m 12 long, 197^m 12 at 50 cents.		98	80
4 forked pivots and their sockets, weighing together 85 kilogrammes, at 1 franc 20 cents		102	
16 bolts with strong screws, 0^m 16 at 90 cents.		14	40
Stopping and plumbers' work for sockets		8	
4 hoops for the top		6	
4 collars with tapped heads and screws, and 4 covering plates, including screws		25	
4 supports of rod iron to support the screw work at each end		50	
4 squares, strengthened with discharging pieces in 28 places, secured by 20 screws and 8 screw bolts		25	
8 twisted catches, furnished with screws to keep the gates open, fixed by 40 screws and 4 covering plates		30	
4 hasps to hinge the gates at the bottom		40	
4 straps for the top		10	
4 bolts with screws for the rails		4	
4 bolts of 0^m 25 to hinge the open bars		6	
4 padlocks at the sides		10	
8 bolts for the arch supporters		20	

	frs.	cts.	£	s.	d.
Total	782	80 =	(31	5	0)

Estimate of the Fencing to be made for the Company of the Paris and Versailles Railway (left bank.) By Lévêque, fence maker, in Rue Rousselet, at Paris, namely—

	frs.	cts.
Fencing of chesnut wood, the uprights set at distances of 21 lines apart, (1¾ inches), supported by five rails, the whole three feet six inches high (3 feet 10 inches Eng.), and pointed at the top, and secured by posts and strong stays also of chesnut, five feet high, pointed, inserted in the ground of four feet distance, at per toise (6 ft. 6¾ in. Eng.) . .	2	90
The same fencing, but four feet high, supported by six rails instead of five, strengthened by posts as supports, at five feet six inches distance, as the former . . . . at per toise	3	15
Similar fencing to the preceding, but supported by posts of chesnut wood, much stronger; that is to say, from eight to nine inches in circumference, whether round or split . . . . at per toise	3	50
N.B. These posts may last ten or twelve year, and the preceding six or seven.		
Trellis fencing, a lozenge-pattern, of three inches, pointed at the top, supported by posts of chesnut-wood, from eight to nine inches in circumference, whether round or cleft; there is to be a course of rails upon these posts, of Baltic fir, fifteen lines thick, and two inches 9 lines wide, strongly nailed to the posts with large pins, and the trellis-work nailed upon the rails and posts . . . . . . at per toise	4	50

Minutes of Specification.—Plantations, Sowings, and Fencing.

The description of plants constituting the supply of fruit or forest trees to be determined by the engineer. The trees to be raised from seed or slips, but never from new wood thrown up from old trunks. To be young and well grown. To be from 10 to 15 centimetres (4 to 6 inches) in circumference, measured above the branches. The holes intended to receive them to be 70 centimetres in every direction in earthworks, and to be increased to a metre in new earth. They shall be moved twice, at least, before planting, and the bottom picked up with a mattock.

The planting to be made between the 1st of November of one year and the 15th of March in the next. The bottom of the holes to be first filled with vegetable mould, well broken up, to the level where the roots of the young trees will

reach when planted, the proper distances and the prescribed lines being observed. The contractor to devote the necessary care of the sowings and plantations of all kinds up to the period fixed for the surrender of the same. It is hereby properly understood that those portions of turf sowings and plantations which are not in proper condition, shall be deducted from the general account.

Estimate.

Each young forest tree, elm, plantain, ash, poplar of all kinds, &c., comprising the digging of the holes, to be 75 cents. in every direction. The filling in with good vegetable mould planting, and taking care of them during the appointed time, to be estimated at 1 franc. (10*d.*)

Each young fruit tree—apple, pear, plum, cherry, &c.—comprising the same as before, to be estimated at 1 fr. 50 c. (1*s.* 3*d.*)

The sowings of the slopes in grass, trefoil, lucerne, &c., comprising the preparation of the slopes and covering them with a layer of vegetable mould if there is occasion, every operation extra charge and allowances to be estimated at 5 cents. 3 dix. the superficial metre ($10\frac{3}{4}$ square feet).

Fencing.

A post and trellis fence, like those uniformly used on the lines in the neighbourhood of Paris, to be put up on both sides the line, composed of oak posts, of 0^m 08 (3 inches) diameter at the smaller end; each piece to be cut or split, to form two posts, which are to be placed at 1^m 50 (4 feet 11 inches) from each other, and driven 0^m 40 (1 foot 4 inches) into the ground.

The trellis-work to be fixed to the posts by nails of 0^m 042 ($1\frac{3}{4}$ inch) long, and of a convenient shape.

The trellis to be of oak or other hard wood, approved by the engineer and fixed in the following manner: six horizontal lines of trellis of 2 to 3 centimetres wide, and $\frac{3}{4}$ to 1 inch by $\frac{1}{3}$ thick on an average, are to be placed at distances of 0^m 215 (8 inches) from each other, as shown on the plan, and the remaining trellises to be of similar section and placed vertically at distances of 0^m 07 (2 inches 75) from each other, from centre to centre. They must be firmly fixed to the former, at each intersection, by fastenings of No. 6, iron wire. When the transverse section of the earth forms an inclined line, the ditch will be only required on the upper side of the cutting or embankment. They are to be enlarged according to circumstances, and may be dispensed with in certain localities on the ower side.

Quick Hedges.

The quick hedges planted on the sides of the railway to be composed of white thorn, (*mespillus oxiacantha.*) Elm may be substituted in gravelly soils which do not suit the above, also the Sainte Lucie or other trees which are known to agree with the soil, and suitable for the purpose of making a good hedge; but this must not be done without the engineer's authority, given in writing to the contractor.

The plants to be 2 or 3 years old, and raised from seed. To be placed in one row, 10 plants for every metre, (3 feet, 3 inches) in the straight parts and in a perfect line, with the utmost regularity along the curves.

Where the railway has no guard ditch, the hedges to be planted at 50 centimetres from the boundary of the land belonging to the company, but where there are guard ditches, they are to be planted at the edges of the ditches on the sides next the line. The contractor must follow the lines drawn out by the agents appointed by the directors.

The hedges ought to be perfectly direct on the straight portions, and they ought to be laid out without any gaps or inequalities along the curves.

The hedges should all be planted by the 1st of March, 1846, or the June following at the latest, to be accepted temporarily, but the contractor will be responsible for two years, and be required to manage them during this time. He must hoe up the earth at least twice, and dig it once each year, and replace the plants which have not taken root; in short, take all necessary care to deliver up the hedge in good condition at the expiration of the appointed time.

Where the soil is strong, the contractor is to report to the engineer, in order that this bad earth may be replaced with good. The hedges to be paid for by the metre, the price to comprise all supplies and work necessary for making the hedges and for their cultivation during the period of the guarantee.

The contractor will receive a certificate for every 10,000 metres (10,936 yards) of hedge planted; one-fifth of this amount will be retained, which will be reduced to one-tenth after all the plantations are finished. The drawback to be paid to the contractor after the expiration of the term of guarantee, and when the plantations are finally surrendered.

The contractor is, moreover, to be subjected to the clauses and general conditions contained in the circular of the Director-General of Bridges and Highways, dated 25th August, 1833, in all that is not contrary to the especial clauses of this specification.

DESCRIPTION OF THE PLATES.

Plate 1.

Details of Earthwork.

The plate represents sections of Cuttings and Embankments under numerous circumstances.

See pages 22 and 23 for a description of the embankment on the Versailles Railway (left bank), shown in the plate; and pages 15 and 16 for that of the cutting, Fig. 2, which is through very soft wet earth.

The covered drain in the Section showing a cutting on a Belgian line through wet land; and situated between the two ways, consists of cut stones, but is only made through those portions which are very wet. It communicates with the side ditches by other small conduits, or cross-drains, which are generally placed about 10 metres (32 feet 9 inches) apart.

The distance between two contiguous aqueducts is often no more than five metres (16 feet 5 inches), where the earth is very wet. Outlets are made upon some parts of the line, furnished with a kind of small drain, by which the water is carried off into the side ditches.

This flow of water is protected by small walls of cut stone, or by a *fascine* sunk beneath it. Old sleepers are also sometimes employed.

The portion of railway on the St. Stevens and Lyons, supported upon piles, and represented in the plate, is situated along the line of the swamp *Caroline du Sud*.

Plate 2.

Specimens of Rails from different Railways.

The following may be taken as a close approximation of the weight of the Rails and Chairs, in use on the principal Railways, and represented in the Plate.

	Weight.		Bearings.		Weight of Ordinary Chair	
	Per Metre.	Per Yard.	French.	English.	French.	English.
	metres.	lbs.	metres.	ft. in.	kilog.	lbs.
The rail from St. Stevens to Lyons is	30 =	(60½)	·90 = ·80 at the joint	(2 11) (2 7)	7 =	(15)
Montpelier to Cette . . .	20	(40½)	0·90	(2 11)	7	(15)
Paris and St. Germains . .	30	(60½)	1·12	(3 8)	9·85	(21½)
Paris and Versailles (left bank)	30	(60½)	1·12	(3 8)	9·60	(21)
Alais and Beaucaire . . .	31	(62)	1·12	(3 8)	10·	(22)
Paris and Orleans	30	(60½)			9·20	(20)
Strasbourg and Basle . . .	25	(50)	0·90	(2 11)	8·50	(18½)
Paris and Rouen	36	(72)	1·28 1·12 at the joint	(4 2) (3 8)	9·50	(20¾)
Grand Junction.	31	(62)	1·12	(3 8)	9·50	(20¾)
The rails of the Liverpool and Manchester vary from	29·70 to 37	(60) to (74)	·90 to 1·12	(2 11) to (3 8)	10·	(22)
London and Birmingham—						
The smaller rail. . . .	31	(62)	1·12	(3 8)	9·50	(20¾)
The larger	37	(74)	1·20	(3 11)	11·70	(25½)
London and Brighton . . .	36	(72)	1·10	(3 7)	10·	(22)
North Eastern	28	(56½)	·90	(2 11)	8	(17½)
Chester and Birkenhead . .	27·72	(56)	0·90	(2 11)	9·45	(20¾)
Birmingham&DerbyJunction	„		„		„	

The joint chairs are 2½ to 4 kilogs. (5½ to 9lbs.) more in weight than the ordinary ones.

The bearings vary upon the Orleans Railway, also upon the lines of St. Stevens and of Rouen.

	m.	ft. in.
In cuttings where the soil is good, the distance between the joint sleepers and those next them, is	1·	(3 3)
And between the others	0·25	(4 1)
Upon embankments, and in cuttings where the soil is doubtful, it is	0·75	(2 5)
And between the others	1·	(3 3)

(The rails upon the Orleans Railway are usually rounded on the top.)

Plate 3.

Specimens of Rails from different Railways.

The rails of the shape of the two first patterns (in the plate), and employed in the United States, are sometimes fixed by a sort of key bolt, the heads of which are of the same section as the hollow part of the rail, and the latter is fixed by *sliding* it along upon the heads of the bolts, which are then passed through holes left in the timbers, and properly secured. The larger rail, above referred to, has been found sufficiently strong to be employed without longitudinal bearings, but the engines run upon them were not heavy.

The double L (⊥) rail or that laid down on the Birmingham and Gloucester, the United States, and the Hull and Selby, is sometimes fixed to the sleepers by means of spikes, which do not pass through the bottom part of the rail, but are taken through holes in a cast iron sole plate, which is made use of, and the head of the spikes projects on the foot of the rail, and hold it down. See the rail used in the United States, in the plate, also the rail tried on the St. Germains Railway, Plate 5.

The Magdeburg rail weighs 21 kilogs. per metre (42lbs. per yard), and the Amsterdam to Haarlem, 30 kilogs. per metre (60lbs. per yard).

The rail employed on the line from Manheim to Heidelberg is fixed by jagged spikes to longitudinal bearings.

The rails of the Hull and Selby weigh 27 kilog. per metre (53 lbs. per yard).

The original rail of the Great Western (the small pattern) weighed 19 kilog. (38 lbs. per yard,) but it was found much too light; the large rails shown in the plate are those at present in use, which weigh 31 kilog. per metre (62 lbs. per yard.)

Plate 4.

Specimens of Rails from various Foreign Railways.

	kilogs. per metre	lbs. per yard.
The rails on the Berlin and Potsdam weigh .	25	(51)
Cologne to Aix-la-Chapelle	27	(54)
Berlin to Dresden	28	(57)
Frankfort to Mayence	30	(61)
Leipsic to Dresden	26	(52½)

The mode of securing the rails to the longitudinal bearings on the Heidelberg to Carlsruhe, and the Haarlem to Leyden railways, is shown in the plate. The

small semi-cylindrical dowels used in connecting the rails at the joints of the former railway, are formed of wood set in cast iron chairs.

Plate 5.

Specimens of Railway Chairs.

The following gives the weight of some of the chairs represented in the plate.

	kilog.	lbs.
Paris and Versailles (left bank)	9.60	(21)
Ditto, joint chair	13.10	(29)
Paris and St. Germains and Versailles (right bank) .	9.60	(21)
Ditto, joint chair	12.	(25)
New chairs Paris and Orleans	9.20	(20)

The chair in use on the London and Birmingham, carries rails, 32 kilogs. per metre, (64 lbs. per yard.)

Plate 6.

Details of the Manufacture of Railway Bars.

Figs. 1 and 3 are sections of bundles for making rails. The parts tinted dark consist of No. 2 iron, and the remaining portions are No. 1 iron.

Fig. 5 represents packets weighing 165 kilogs. (364 lbs.), which are used at the Decazeville Iron Works, when the No. 1 iron is of inferior quality.

Fig. 2 is a section of a bundle for the manufacture of *covering pieces;* and Fig. 4 shows another arrangement for the same; Fig. 6 is the bundle used at the Creusot Foundry, for bundles of the largest size, or fig. 9.

Fig. 7 represents pieces of No. 1 iron, to fit into the bundles fig 4, for coverings.

Fig. 8. The pieces of No. 2 iron, to fit into the bundles fig. 5.

Fig. 9. A section of a rail of the largest size, made of packets fig. 6.

The finishing cylinders used at the Terrenoire Works were employed for making the rails of the line from Andrezieux to Roanne, (after M. Walter's plan.)

The horizontal screw lever (see Plate) is employed at the Creusot Works for redressing the rails.

The rail R R, is placed upon friction rollers, supported by carriages upon a cast-iron bottom plate, S, and it is maintained firmly in its horizontal position

by pillows T T, the position of which can be altered according to the nature of the curve affecting the rail. The most prominent part required to be straightened ought to face the screw V.

P is a piece of iron placed between the screw and the rail.

V V. The great screw which passes through the brass screw-box, E, bears a large cog-wheel, G: a pinion, N, is fixed upon the shaft which carries the wheel, L, and a winch, M. Two men are employed to work the machine, one acting upon the arm, *m*, and the other upon the winch, M.

This apparatus has been adopted in England, and works very well.

Plate 7.

Details of the Manufacture of Railway Bars.

The Double Saw represented in the plate is a machine employed in England for cutting both ends of the rails at the same time.

It is made moveable in order that the length of the rail may be varied, if required.

It is composed of an open table, A A, one of the upper edges of which is cut with a bevel, to enable the stages supporting the saws to slide along as may be required.

The rails are supported on two small platforms, B B, which are subjected to a movement perpendicular to that taken by the carriages of the saws, which is accomplished by means of racks C; the rails may consequently be placed either close or distant, as desired.

The racks are maintained firmly by rollers D, D, placed above small pinions E, E, which can be moved by the hand, by the aid of the wheel H.

The saws receive a rapid rotary movement by means of bands passed round the band-rolls F, F, which are put in motion by the steam-engine. They make about 1000 revolutions per minute, and the rail is cut in 12 or 15 seconds.

We observe from this mode of arrangement—

1st. That the distance of the saws can be regulated as required.

2ndly. That they are rendered perfectly parallel.

3rdly. That the parallelism of their axes, with that of the rail, is insured by the strength of the pieces which carry the saws and the rail.

These are the chief conditions required to be complied with in machines for cutting rails.

The saw is covered during the works by a cowl or plate-iron cap, which protects the workmen from the incandescent dust discharged at the time.

The single saw cuts one end only of a rail at a time.

The rail R, R, is supported by two brackets, *a a*, cranked upon an horizontal shaft, *b*. The latter is strongly supported on three carriages—*c*, *c*, *c*, which are bolted upon the foundation plate, A; piece *e* is also cranked upon the shaft *b*, and intersected by a screw, *f*, by the aid of which the former is carried backwards or forwards, and the rail applied or withdrawn from the teeth of the saw.

This saw is employed at the works of Terrenoire, in France, where it passes through a vessel filled with water, and performs with the requisite accuracy.

Plate 8.

Details of Railway Tools.

This plate represents the principal tools in use in the formation of railways in England.

Plate 9.

Details of Tools for Laying the Rails.

These describe the tools employed on the Versailles Railway, (left bank.)

The *Anvil* is employed for redressing the rails, and the *chisel* for setting the joints at the proper distance apart. The chair wedges are adjusted by the *iron chaser*. The *levelling lever* is made of a suitable form at one end, to embrace the rail, and the rail lever is used for raising them.

Plate 10.

Strasbourg and Basle Railway.

This plate shows the tools used on this line of railway.

Plate 11.

Details of Mr. Stephenson's Switch Rail.

This switch consists of a moveable rail R″, fixed in a chair H Q, by a bolt, which allows it to turn laterally. (See chair at A H Q enlarged.)

The rail R″ is connected by a rod E to a lever P, by a moveable axle (to

which a weight N is attached), a handle also being connected to the lever. (See details of lever.)

The action of the weight N keeps the moveable rail pressed constantly tight against the rail S S′, and effects a passage along the line R R′.

If a train advanced along the rails S S′, the switch rail R″ would be thrust away from the rail S′ by the flanges of the wheels, but would resume its original position immediately after the passage of the carriages. A train coming in the opposite direction would pass into the oblique line, provided the switch R″ remained pressing against the rail S′, or it would proceed straight forward on S′, if the point was turned by the lever on the rail R″ moved from S′, but the train cannot get off the line in either case, as with the original switches employed on the St. Germains railway. (See the Text.)

The switch chair A H Q is composed of two distinct parts cast together, *that is to say*, the chair A, with the cast-iron plate Q. The latter is pierced in the middle by a circular hole to receive the bolt *b*. The chair H is fixed to the bolt by means of a pin *c*, and turns round the former.

The switch rail R″ is maintained in the chair by means of the bolt *d*.

Plate 12.

Details of a Switch Rail adapted for three Lines of Railway.

Upon the points being placed as shown upon the plan, and a train advancing by the line N, V′, it consequently passes into the middle line, M, M′. This may be called the *normal* or regular position of the switches, and which the counterpoise P, and P′, enables them constantly to maintain, excepting when acted upon by the lever, the position of which is vertical. If the switchman lowers the lever, the bar, which is furnished with a counterpoise P′ at the extremity, is raised. The rods t″ and t‴, as will be readily perceived by reference to the section, are drawn in the direction of A and A′, and the switches A and A′ are pressed against the points B and the counter rail R on one side, and against the point B′ on the other, by which the train is enabled to proceed along the line N N′.

If, instead of lowering the lever, it is drawn in the opposite direction, the cam *c* operates by raising the bar with the counterpoise P at the end of it, and the rods t and t′ are pushed in the direction B′ A. The point B′ is forced against the point A′ and the guard rail R′ R′. The point B against the point A and the third way V V′ is then open for the train.

The iron box at A, L, B, contains the rods by which the points are shifted. It is represented open in one of the figures to explain the interior.

The section at C D shows the counterpoise P.

Plate 13.

Details of Switch, London and Birmingham Railway, and Details of Switch Box, Orleans Railway.

This change of way very much resembles that of the St. Germains represented by Plan No. 2, Plate 20, and, like it, presents the inconvenience of exposing a train to fall upon the ballasting, if by inattention or malice the crank should be improperly placed.

It is composed of two double switch-rails, D, D′, and D, D′, bound immovably together by tie rods E′ and E′. The two rails forming each double rail are united by bolts *e*, *e*, and fixed in moveable chairs, H, H′, by bolts, *b b*. The rails R″, R″, may be placed at one time opposite the rails D, D, and, at another, to the rails D′, D′, by means of an eccentric, M, and consequently open a communication between the way either with that of R″ R″, or that of S, S. The way formed by the rails R, R, and by that of R″ R″ is shown continuous in the plan.

It will be seen that the chair H, differs but little from that described in Plate 11, (A, H, Q,) and rests like it upon a shoe Q, cast together with the chair A. A bolt passes through the latter which permits the rails D and D′ to describe an arc of a circle, whenever the switch rails change their position.

Plate 14.

Details of changing place for three Lines of Rails employed in Belgium, and Details of Switch Plate employed for two Lines.

This switch, with three throws, differs from that originally employed on the St. Germains Railway in this respect only. The switch rails D, D, can place the line R, R, in communication successively with three lines. It may be the cause of serious accidents, like the preceding, if the rails D, D, do not follow the same direction along the line as the general run of the trains or engines.

A different mode of working the switches is shown upon the plate by "Another Plan, &c.," with an eccentric instead of a crank.

The switch represented in the Plate is furnished with moveable guard rails, and is employed in Belgium for a double line.

The guard rails are formed of wrought iron, but the foundation upon which they slide consists of cast iron, and the portions of rails connected with the same are cast upon it. They rise above the surface upon which the guard rails slide.

Plate 15.

Details of Switch for changing the Line.—Basle Railway.

The system adopted on the Basle Railway is nearly the same as that on the Versailles (left bank), represented in Plate 16. It is only in the arrangement of the eccentric, of the wood work upon which the rails are fixed, and in the form of the chair, that it differs.

The usual oak sleepers without longitudinal pieces replace the foundation we have described for the switches upon the line of the left bank, which rendered the establishment of the changing place very expensive. The chairs H K I, placed symmetrically on each side, the details of which are given, permit the guard-rails D D to slide along easily, without the assistance of longitudinal pieces in the same plane as the rails.

The eccentric is enclosed in the switch-box, and cannot be touched without opening the door P, which is locked, the key is shown with the lock, &c.

The plans are taken at the levels of the eccentric and of the door P. The centre and guard-rails, in the crossing point, are fixed with screws.

			kilogs.	lbs.
The chair at H, upon which the guard-rails turn, weighs			20·20	(45)
Do. at K,	"	"	13.70	(30)
Do. at I,	"	"	15·20	(34)
Do. at L,	"	"	13·70	(30)
Do. at O,	"	"	17·80	(39)
Do. at M,	"	"	15·80	(35)

Plate 16.

Details of Changing Place.—Paris and Versailles Railway (left bank).

This changing place is furnished with *check rails*, and arranged in such a manner that, notwithstanding whatever position the switch may be in, the trains will not leave the line.

It is composed of two pair of rails, R R′, S S′, each being set at a uniform

distance of 4^{m} 50 apart, or (4 feet 11 inches from centre to centre,) and fixed in chairs of a particular form, M N O P, (See Plate 18.)

The two guard-rails, D and D′, are bound immoveably together by means of an iron rod E, and turn in the chairs H round the bolts *b b*. They receive an alternating movement horizontally, by means of a cranked axle enclosed in a box, which communicates with them by a rod F. They are pressed at one time against the rail S, and at another against the rail R, accordingly as the train is required to be directed upon the rails R R′, or upon the rails S S.

The switch-box is found hollow in the form of a half column, and incloses a crank placed upright upon its axle, and which is connected with the rod F. This axle turns in a socket *q*, at its lower extremity, and in a brass chair at its upper part, maintained by an iron plate *r* and two bolts. An arm *u*, is fixed upon the handle *m*, and pierced by a square hole at its extremity to receive the pin *a*, which passes through it into the upper plate *p*. The guard-rails D and D′ are thus maintained in one of the two positions which they are required to take, as may be necessary.

In the details of the eccentric employed on the Liverpool and Manchester Railway, represented in the Plate, we may state that the use of the square collar has been abandoned, and the elliptical one substituted.

Plate 17.

General Plan of Change of Way for two Lines, Paris and St. Germains Railway, and Plan of Crossing-place for two Lines, Versailles Railway, (left bank.)

The general plan of the change of line is arranged for switches formed with moveable rails.

The crossing-place is composed of a frame formed of two wooden longitudinal pieces *b b*, fixed solidly together to four transverse sleepers, *a*, *a*, *a*, *a*, by the aid of bolts. These sleepers carry the chairs A, B, C, D, E, F, which are called *switch-chairs*, and secure each pair of rails R, R′, R″, R‴, parallel together, so that the guard-rails are enabled to direct the train.

	Kilog.	lbs.
The chair at E, E, E, &c., weighs . .	17·20	(38)
Ditto at C	30·60	(67)

Plate 18.

Crossing-place for two Lines, Versailles Railway (left bank).—Details of Chairs.

		Kilog.	lbs.
The chair at A weighs	. . .	19·	(42)
Ditto at B	„	23·10	(51)
Ditto at D	„	13·6	(29)
Ditto at H	„	15·10	(33)
Ditto at N	„	16·50	(36)
Ditto at P	„	21·80	(48)

Plate 19.

St. Germains and Versailles Railways (right bank)—Change of Way at the Asnières Junction.

The switch and crossing rails employed by M. Clayeron, at this junction, are constructed in such a manner that one cannot be altered without the other being at the same time shifted. This plan has the effect of preventing any irregularity of the crossing-rails, which is so general with those of the usual construction.

The contrivance consists of a longitudinal beam E F laid by the side of the line and supported on small standards, which receive a shaft upon which there are four eccentrics, C C′ C″ C‴. The required motion is communicated to the switch and crossing-rails by means of two wheels, D D′.

In the details of the shaft, &c., represented in the Plate, P is one of the standards supporting the shaft, Q an eccentric, R a collar embracing the eccentric, and O one of the stops which arrest the wheels D and D′. The coupling boxes, shown in the details of the switch rods, serve to regulate the length of the rod between the two switches.

Plate 20.

Details of Switches employed on the St. Germains Railway.

Plan. (No 1.)

This represents another *check-rail switch*, and only differs from that on the Versailles Railway (left bank) shown in Plate 16, by the length of the guard-rails

and the arrangement of the frame and crank rods, which may be lengthened or shortened by means of screw-boxes, F, as necessary.

PLAN. (No. 2.)

This switch consists of *moveable rails*, and was formerly in use upon the St. Germains Railway, but has been subsequently abandoned on account of being considered dangerous. The trains were liable to get off the line, if the switches, either by wilfulness or inattention, were placed wrong. (See Text.)

PLATE 21.

St. Germains Railway.—Details of Chairs for Switches and Crossing-rails.

The relative situations of these chairs will be found by studying Plates 16, 17, 18.

			kilogs.	lbs.
Weight of chair H (See Plate 20)		. . . .	20·71	($45\frac{3}{4}$)
Do.	„	2	20·50	(45)
Do.	„	3	21	(46)
Do.	„	4	13·30	(29)
Do.	„	5	14·59	(32)
Do.	„	6	13·90	(31)

PLATE 22.

Paris and Orleans Railway.—Details of the new Switches and Crossing-points.

The action of this switch is similar to that of Mr. Stephenson's, represented in Plate 11, with this difference: the fixed switch point is replaced by another moveable switch rail.

The section on C D shows the wedging blocks placed between the switches, and the rails to secure the switches from lateral pressure.

PLATE 23.

Paris and Orleans Railway.—Details of the new Switches and Crossing-points.

The old pattern chair used at R and Q, Plate 22, and represented in this Plate, after having been employed some time, was found defective, from the bolt

n, shown in section at *m*——*n*, making too much play, by which a dangerous movement occurred throughout the entire switch. A new pattern chair has been, consequently, substituted, in which the horizontal motion is very trifling, and the switch is maintained better vertically.

The old pattern chair is formed of two distinct parts; the larger one, *a b c d* (See Plan), is fixed and let into the woodwork at *g*. (See the other Figures.)

The smaller chair, *e f*, rests upon the plate of the former, and is joined to it by the bolt *h*, which, however, permits of its turning when the switch is moved. The bolt *h* (see the section at *m*——*n*), represents the pivot of the switch rail, and, after passing through the two pieces forming the chair and the timber beneath them, it is keyed.

The weight of this chair is as follows:—

	hectogr.	lbs.
The large portion	340	(75)
The smaller portion	91	(20)
	431	(95)

The new pattern chair is attached to the head of the switch at *a a*, and the connexion is maintained very close at this part; but the chair is enlarged on each side of it, in order to allow of the requisite motion to the switch, when it is required to be shifted.

The weight of this chair is 315 hectogrammes, (69 lbs.)

The chairs at R R R are placed at different distances along the switch, (see the last Plate.)

The rail on the right in the section represents the switch. The weight of each of these chairs amounts to 116 hectogrammes, (25 lbs.)

The following chair is, however, preferred, as it offers some support to the switch at *a a*.

The chairs at U and V weigh 133 hectogrammes, (29 lbs.)

Plate 24.

Paris and Orleans Railway.—Details of the New Switches and Crossing-points.

The crossings on the Orleans line are more than a hundred in number, and are all formed exactly alike; the chairs are therefore made of the same pattern.

	hectogr.	lbs.
The chair A, which is the first on the crossing past the switch, weighs	216	(48)
Do. B,	249	(55)
Do. C,	213	(47)
Do. D,	140	(31)

Plate 25.

Paris and Orleans Railway.—Details of the new Switches and Crossing-points, and Details of a Crossing-place at right angles.

The chairs at K S and T (Plate 22,) are placed between the heel of the switch and the point in the change of way.

	hectogr.	lbs.
The Chair at K weighs	160	(35)
Do. S	150	(33)
Do. T	141	(31)

The Chair for "rail and guard-rail" is employed exclusively at all parts where there are guard-rails. One of the rails shown in the section is the guard-rail.

We may observe, in the details of the crossing-place at right angles, that the rails a and a' in the plan are not broken off, but are merely notched out on their surfaces to form a passage for the flanges of the carriage-wheels passing along the rails b and c.

The lower portions of the rails remain perfect, by which any movement horizontally from the passage of the trains is prevented.

The other rails $b\ b'$ and b'', $c\ c'$ and c'', are broken off and fixed by wedges.

Plate 26.

Details of the large Turn-plate at the Derby Railway Depôt.

This table rests upon two circular iron ways $c\ c'$, laid at the bottom of the well-hole.

There are moveable friction rollers running on the smaller circle c, which support another circle of the same diameter and width. Two long timber beams $p\ p'$ are fixed upon the circle, and secured by iron cross pieces $t\ t$. These pieces are employed to carry the rails, and are supported at their extremities by

means of cast-iron fittings resting upon the axles of four friction rollers $g\ g'\ g'$ and g'', which run upon the outer circle $c'\ c'$. We may, therefore, consider the large Derby turn-table as a platform of small diameter, with the rails lengthened.

It is put in motion by turning the handle, shown at g'', which moves the friction roller g''', and by the reaction of the latter upon the circular rail $c'\ c'$; the plate is at the same time turned, and the other friction rollers follow the movement.

Plate 27.

London and Birmingham Railway.—Details of a Twenty-one feet and of a Twelve feet Turntable.

The large turn-table represented in the plate is erected in the locomotive rotunda at Birmingham.

It is composed of four distinct parts:—1stly. Of a cast-iron curb A A, which is cast in two semicircles of a depth equal to that of the well-hole. The lower part forms a circle, upon which the friction rollers run, being supported on a foundation set in masonry.

2ndly. Of an iron bearing frame, formed with four branches B B B B, the extremities of which receive the circular curb. The socket is also fixed at the intersection of the branches in the centre of the table.

3rdly. Of eight conical friction rollers maintained between two iron circular plates.

4thly and lastly. Of the table itself, upon which the wrought-iron rails are fixed perpendicularly to each other, which afford the platform means of communication with the different ways.

The frame of the smaller turn-table is cast in a single piece.

Plate 28.

Sections of a new description of Turn-table.

Fig. 1.

This turn-table consists of a fixed column A, terminated by feet B B, which are embedded in *beton* or concrete. The table is fastened to an outside jacket C, which is moveable upon the column. The arms D D transmit the weight of the table to the base of the column, and serve at the same time to stiffen the apparatus. The globular eye-piece at the top, and the ring-piece $e\ e$ below, between

the jacket and the column, facilitate the motion of the table. The latter is supported on a circular girder resting on friction rollers, arranged upon a suitable bed at the foundation.

A cast-iron curb plate E E skirts the table, which is laid upon timber framing, resting directly on massive masonry.

Fig. 2.

This also consists of a fixed column A, but with a conical shaped foot, extending very wide at the bottom. It serves as points of support for the stays B B, which rest on, and are fastened to, the circular lining of the well-hole. The arms D D, supporting the table, are bolted to the same, and to the jacket E E, by which the whole of the moveable parts of the platform are secured together. The ring-pieces *e e*, at the top and bottom of the column, facilitate the motion, and prevent any oscillation, whereby the friction rollers, usually placed at the circumference of the foundation, are enabled to be dispensed with. This turn-table is not intended for moving locomotive engines or tenders, but for carriages of less weight.

Fig. 3.

This is a large turn-table, intended for shifting an engine and tender at the same time; it differs from Fig. 1 by having an additional set of arms, which are rendered necessary by the increased dimensions of the machine. The employment of horizontal friction rollers, A A, at the bottom of the column, in place of a metal ring, changes the sliding to rolling friction; the former would otherwise be considerable.

The Balance Turn-table.

Fig. 5.

This turn-table rests upon a horizontal crownpiece, A A, forming the head of the moveable column B. The jacket is fixed and secured by the aid of rods C C, to arms D D, which support the circular curbing, E E, enclosing the table.

The rods and screw-boxes F F, serve to maintain the vertical position of the column.

The box G, enclosing the socket, transmits the entire weight upon the table, (by means of stirrup pieces H, attached to it, and secured on each side of the balance beam at I,) which it receives from the fixed jacket, to the balance beam, being secured to it at the centre of oscillation K.

Section explaining the Action of the Balance Beam. (*See fig.* 5.)

Fig. 4.

When the lever L is raised, the balance beam oscillates round the point K, and describes a small arc of a circle at the point I, of which K I, is the radius.

The column then becomes raised from its base, and the table consequently disengaged at the circumference, *a a*, when it may be turned with the greatest ease, however burdened.

Fig. 6.

The plan of this turn-table is very much like fig. 5. It is only used for passenger and goods' carriages, and is consequently not calculated to bear much weight, much less engines; the balance beam is therefore omitted, and the extremities of the table are not required to be supported upon an outside curb. The catches A A, are employed to fix the platform in whatever position may be required.

Plate 29.

Turn-plate employed upon the Great Western Railway.

The surface of the table is floored with planks fixed to the iron work by bolts of 0^{m} 013 (0in. 511) in diameter. The holes for the bolts are drilled when cold, the heads of the latter being dipped in grease.

The planks are 0^{mm} 55 (2 in.) in thickness, ploughed along the edges, and secured together with iron tongues. The flooring is maintained in its position by a large iron circle, and by a cast iron centre-piece, as shown in the plate, and tarred over, for the purpose of preservation. The table is raised and displaced by means of a large screw, the head of which is furnished with a ring. Upon being introduced into the hole of the plate, a nut is screwed on the extremity upon which the plate is rested when the men raise it.

The rails are fixed upon the plate by bolts which pass through the planking and cast iron framing.

Plate 30.

Strasbourg and Basle Railway.—Timber Framing enclosing Turn-tables.

These foundations have the effect of rendering the turn-table perfectly secure. They are composed of timber frames, placed upon each other. The first, C C, D D, and E E, F F, is of a rectangular form, and supported on eight piles, *a a*, with the side pieces halved and notched. The second, G, H, I, K, is of larger dimensions, and supported on four piles, *b b*. It bears the cross timbers upon which the socket is fixed, and the iron circle which receives the friction rollers. The several polygonal pieces forming the circumference also rest upon it. This frame differs but little from that represented in Plate 35.

Plate 31.

Turntable for a Locomotive Engine and Tender employed in Germany.

This turntable consists of a cast iron nave, upon which the girders, A, A, supporting the rails are bolted, also the intermediate girders, B B, which connect the large outside ring with the nave. The girders, I I, connect the main girders together, and maintain them at the proper distances apart.

The whole of the surface covering between the rails is formed of cast-iron, which prevents the embers from the engines doing any damage; the remaining portions of the table are covered with wood.

The friction-rollers E are fixed to the girders by means of uprights, F, F, resting on the bearings G, G. The pivot is secured to the nave by means of four long bolts. The cast-iron socket H is secured to the foundation by means of very strong bolts, as shown in the Plate: a steel eye-piece is placed in it to receive the pivot.

There is a circular plate K, passing round the bottom of the well-hole upon which the rollers run. The circular curb D is formed with toothed racks next the well-hole. The table is turned by means of a winch, consisting of a standard and two handles, by which the motion is transmitted to the toothed wheels L, M, N, O. The latter are secured to the table by cross pieces of cast iron.

The toothed wheel L, being in contact with the circular rack D, effects the movement of the table.

Plate 32.

Versailles Railway.—Timber Turn-plate employed on the left bank for Goods Wagons, &c.

The rails upon the turn-table *a*, *a*: *b*, *b*: consist of pieces of flat iron, screwed upon the planking covering the turn-table, and serve to direct the wagons which are required to be turned. The iron crossing-pieces *d d*, form inclined planes, which are intended to support the edges of the wheels, and prevent their receiving a shock from the break in the rails. The iron bolts *f f*, which are half-lapped at *g g*, and morticed and tenoned at *h h*, serve to secure the timbers properly together.

Plate 33.

Details of Foundation of Turn-table, Versailles Railway (left bank).

This foundation with the turn-table is built on the Versailles Railway (left bank), in the centre of a polygonal carriage depôt. The lining of the well-hole is maintained by a stone wall, surmounted by two circular tiers of timber composed of segments *c c*. The rails of the twelve lines of way for the service of the locomotive engines in the rotunda are laid upon longitudinal timbers along the sides of the trenches H H. They are directed towards the centre, as shown in the plan, by crossing-points formed of wood and iron, F F, which are fastened to the rails.

The water which falls into the trenches is carried by means of drains B B, into a culvert A, running round the well-hole, which is discharged by a special drain into a dry well or a cess-pool placed on the outside of the depôt. There is also a drain D, from the well-hole of the turn-table into the circular culvert A.

Plate 34.

Turn-table for a Locomotive Engine and Tender.

The platform, or table, (properly speaking,) of this apparatus, consists of a large disc formed of strong planking A A, supported on a cast iron framing composed of four principal pieces B B, and C C, securely fastened and maintained at the proper distances apart by cast iron cross pieces and bolts. The rails are

placed over the girders B B, and fixed to the planks by screws. Two cast iron cross pieces are bolted between the large girders B B, and C C, parallel to each other, to receive the friction rollers, the axles of which turn in the chairs cast upon them. These axles are formed of wrought iron turned at each end to about 98 millimetres (4 inches) diameter to form a pivot, and are fixed to the centre of the friction rollers by a key, as shown in the details. The friction rollers are placed very close to the two large interior girders B B, and are fixed at unequal distances apart, which is contrary to the usual mode of arrangement adopted with small turn-tables for receiving engines, and carrying four rails. The rollers of the turn-table represented, are modified in order to support the load more efficiently. The friction rollers run upon a circular iron way, supported on an octagonal wooden framing let into the masonry of the foundation.

The turn-table is moved by means of a handle connected with the spindle of a pinion, as described in the plan and details.

The section of the " bevelled gear and frame supporting the spindle," refers to one of the cross pieces, which receive the pivots of the axles of the cog wheels and friction rollers. The outline of the gearing is shown in this figure by dotting.

The section of the " moving gear" exhibits a transverse section of the pinion of the bevelled gear, and of the cross pieces which bear the axles.

The elevation of " cog wheel and pinion" is taken in front. The cog wheel is borne upon the axle of the friction roller, which is also shown in the Figure.

The position of the friction roller is fixed by means of the adjusting screw applied at one of the extremities of the axle.

Plate 35.

Strasbourg and Basle Railway.—Details of Turn-tables.

This turn-table is laid upon a grating of timber set in masonry, and is very highly approved of.

Plate 36.

Details of Railway Weigh-Bridges.

Figs. 1, 1′ and 1″, represent a weigh-table.

The section is taken through the vertical axis of the table, which consists of a fixed socket B, maintained above and below by arms B′, B′, and B″, B″, also by

rods t, t, and t'', t''. The column A is terminated by the head-piece A′, A′, which supports the framing C, C, of the platform. It rests upon a socket, which constitutes the piston of an hydraulic press P, which it moves in a vertical direction.

The socket-box D is fastened by stirrup-pieces at q, to the balance-beam X, and the latter oscillates round the point p, which is fixed to the jacket B.

If the socket is raised by means of the hydraulic-press P, and the platform consequently elevated, all contact at the points a' a' ceases, when the platform can be easily turned; the whole of its weight, moreover, would bear upon the socket D, and be transmitted from thence to q, upon the balance-beam X, which would thus be enabled (by means of the moveable weight R upon the graduated lever L) to show the exact weight with which the platform was loaded.

The counterpoise S serves to equalize the weight of the platform, the dead weight of which varies according to description of the carriage being weighed.

Some of the planks are raised in the "Plan of the turn-table," to show the arrangement of the pieces employed in its construction.

Fig. 1^3 is a section through the centre of the socket D. The exterior box affords a communication with the hydraulic-pump P, by means of the pipe T; the socket being pressed by the column A, consequently acts upon the piston, and either raises or lowers it in this box. By the assistance of a stuffing-box K, all escape of water is impossible.

Figs. 2′ 2″ 2‴ 2⁗ illustrate a smaller weigh-table.

This differs from the former merely in the omission of the hydraulic-pump. The entire weight of the platform always rests upon the socket D, which conveys the pressure to q, upon the balance-beam X, as in the preceding. The lever l is employed to work the rods $t\,t'$, which stay the position of the platform, and lodge it firmly on the circular curb of the lining.

Figs. 23 and 24 are sections of the socket. The box D is fastened to the balance-beam by rods n n, furnished with nuts. M is the steel socket; $r\,r$ a metal ring, which serves to diminish the friction.

Plate 37.

Level-Crossings and Gates.

The different plans of crossings are fully described in this Plate. The gate-posts should always be fixed very securely with struts and masonry.

Plate 38.

Details of Draw Bridges on the St. Germains and Rouen Railway.

A double Hoist-bridge.

The bridge is situated at a height of 1^m (3 feet, 3 inches) above the line of railway V V′, and is composed of four leaves, or moveable platforms, supported on wheels as shown by the section. The wheels rest on two auxiliary ways, V″ and V crossing the principal way V and V′.

Upon the flaps being lowered, they constitute a footway by which the passengers and men connected with the works pass to and fro. The way V and V′ conducts to one of the departure sheds. When it is required to take a passenger coach across the line of footway from the shed to the departure line, the four leaves (as shown in section along the line X Y) which turn upon the hinges *h e* and *g e*, are raised. The wheels which carry the leaves run back upon the auxiliary rails V, V^2 and V^3, and the articulated axle changes its position as shown in the section. P is a counterpoise which prevents the flaps falling with too great violence when they are lowered.

A single Hoist Bridge.

This bridge consists of a single leaf, which, upon being lowered, forms the footway. The leaf is fixed firmly on three wheels, R R R placed upon three rails. Each outside wheel is furnished with a flange, in gear with the outside rails, but the middle wheel is formed without any. The section at Y Z, shows a section of a portion of the departure line (V), which is taken to a shed on the other *side* of the draw-bridge.

When it is desired to pass a carriage from the sheds to the station or the contrary, they hoist the bridge which enables them to use the railway, and the wheels connected with the leaf turn and run on the rails supporting them. The counterpoise eases the fall of the leaf when it is lowered.

Plate 39.

Moveable Machine (Baleine) for executing embankments.

This ingenious contrivance was first employed on the St. Germains Railway, by M. Clapeyron, engineer in chief of the railway.

It consists of two trussed beams, which are laid with rails. It is placed at the head of the embankment during the course of execution, the earth wagons being run upon it after being tipped. Suppose the formation of an embankment proceeding from one end of a cutting, the baleine is placed as shown in the plate with one end resting upon the embankment, and the other laid in the same line of direction, and supported on a wheel carriage. The carriage stands on a small auxiliary railway proceeding from the lower level of the head of the embankment, the rails being taken up at one end as the other progresses.

Upon a wagon being tipped (at the battery head) and the contents discharged between the rails, it is then pushed to the further end of the baleine. This course is followed with a second wagon, which is also discharged and run on the baleine, next the first, and it is continued until the baleine cannot accommodate any more, when the whole of the wagons are carried back together to the places of filling, by a horse or a locomotive engine.

The workmen move the baleines forward upon the wheels of the carriage supporting it, by crow-bars and other tools. They also raise it by ropes and pulleys to whatever height may be required at the head of the embankment.

Plate 40.

St. Germains Railway.—Details of Changing and Crossing Places for Temporary Works.

This crossing-place is formed of wood and iron. The iron edging the pieces of wood being fixed by bolts, as shown in the Plate.

Plate 41.

Details of Changing-place for Temporary Works.

The moveable rails at the points C and B are placed between the spikes employed in fixing them upon the sleepers, as shown in the detailed plan. The rails slide upon these sleepers in the plane of the way, and are placed at one time in the direction of the principal way, at another in the branching off line.

There is a third moveable rail at A, which is the depth of a rail higher in its level: it slides upon the surface of the other line, which is fixed. When the wagons proceed along the oblique line, they consequently run over the crossing above the direct line (*i. e.*, *upon it*). When, on the contrary, they are running along this line, the moveable rail A is displaced, and *slid* into the position shown

by the dotted lines, by which it is out of the way of the flanges of the wheels. The difference of level consequent upon this arrangement between the points C and A renders it necessary to lay the rails, or the ends of the rails, between these two points with *slopes* upon supports properly adjusted with the sleepers of the principal way.

The height of a rail being ·08^{cm} (3·15 inches), and the distance from the point C to the point A equal to the length of the two rails 9^{m} 16 (30 feet), the inclination of this slope is therefore found to be about ·0145 (1 in 114), which is not objectionable for a short distance, even for the speed requisite in transport with locomotives.

Plate 42.

Paris and Versailles Railway (left bank).—Changing and Crossing Places for Temporary Works and Sheaves of the Self-Acting Plane (Plan Automoteur).

The sheave was made use of on the self-acting plane employed on the works at the cutting of Clamart on the Versailles Railway (left bank). See the Documents.

The small wooden voussoirs forming the side cheeks round the periphery of the pulley were found deficient in strength, and were consequently several times broken, or detached, from the effects of the cord pressing them. It would be necessary in constructing new pulleys to make these voussoirs thicker, and to fix them with good wooden screws or small bolts instead of nails. It is also important that the neck of the pulley should be enclosed in such a manner as to prevent the rope leaving it.

Plate 43.

Details of Wagons for Executing Earthwork.

No. 1. Wagons employed on the Versailles Railway (left bank).
This wagon is tipped at the end.

No. 2. Ditto ditto.
This wagon is tipped at the side.

No. 3. Wagons employed on the Versailles and the St. Germains Railway.
This wagon may be tipped both at the side and at the end.

No. 4. Ditto. ditto.
This wagon is tipped at the end.

Plate 44.

Details of Wagons for Executing Earthwork.

These comprise the chain stops, flap hinges, tilting pivots, wheels, and grease boxes, clasp-iron, draw-links, hooks, limber, &c., of wagons employed on the Versailles and St. Germains Railway.

Plate 45.

Details of Wagons for Executing Earthwork.

No. 1. Wagons employed on the London and Birmingham Railway.
This wagon is tipped at the end.

No. 2. Ditto. ditto.
This wagon is tipped at the side.

No. 3. Wagons employed on the Great Western Railway.
This wagon is tipped at the end.

No. 4. Ditto. ditto.
This wagon is tipped at the side.

Plate 46.

Details of Wagons for Executing Earthwork.—Great Western Railway.

These comprise the iron chain-strap attached to the flaps (of No. 4, in last plate); chain-straps to another wagon (No. 3); wheels, axles, grease boxes, &c.; tilting shaft, clasp irons, which are employed to hold the body; side break-irons of Nos. 3 and 4. This bolt forms the fulcrum of the break, the flat part being bolted on to the side-frame of the wagon; hook for drawing, placed at the extremity of the longitudinal piece under the body; handle of break; strap through which the irons pass which sustain the flaps; hook for grease boxes fixed at the end of the frame; draw-link, by which the chain is attached to the end of the wagons; chain-hook for supporting the break; and the strap at the end of the flaps, which serves for hinges.

Plate 47.

Details of Wagons for Executing Earthwork—London and Birmingham Railway.

These comprise the turning or tilting pivot; iron chain stop attached to the flaps; hinges, wheels, axle, and grease boxes; draw-link (7) placed at the extremity of the frame; draw-link (8) placed at the other end of the same wagon; hook (9) for sustaining the break; bolt (10) forming the axis of the break, which is passed through the frame; traction-rods placed in the middle; clasp-irons for holding the body; and the lever-break.

Plate 48.

Details of Wagon for executing Earthwork.

No. 1.

The wagons, No. 1, were employed on the Northern Railway, and No. 2 on the Rouen line, by M. Nepveu, architect, contractor of the three first contracts of earthworks on the Northern Railway. They differ from each other in this respect —The four wheels of the first are united by a peculiar frame, but the wheels of the second wagon have no frame, and are merely united in pairs at the middle of their axles by a wooden shaft secured with irons. We perceive, by the side elevation of No. 1, that the body of the wagon is inclined. The vertical irons situated in the centre, and shown in the front view, and which are seen at large in the following plate, prevent the wagon from tipping. It is not merely necessary to raise the clasp, and separate the pieces in the operation of tipping, the wagon requires to be pushed forward, and then arrested suddenly by cross pieces of timber, placed below the rails. The wheels fall in this opening, and are stopped, when the body is immediately tipped with the requisite velocity. The wagon rests in this position until the wheels are brought back upon an horizontal plane. This wagon contains two cubic metres of earth, (2·6 cubic yards.)

No. 2.

This is much lighter than the last. It is said that M. Nepveu gives it the preference.

The bodies of each are nearly the same in weight; we perceive by the elevation of the " side without the wheels," that the grease-boxes are not alike on both axles.

No. 3.

This wagon has a moveable body, which is pushed forward, and run upon friction-rollers, when it is tipped, the frame being stopped short suddenly; V is retained by hooks, one on each side. The body, the two friction-rollers, and the hooks, are shown at a and a'.

No. 4.

This wagon is formed partly of plate iron, and was employed on the Paris and Rouen Railway. The upper part consists of wood, and the remaining portions of the sides and the bottom of plate iron of 0^{m} ·0035 (·1377 inch) in thickness. The body tips upon the hindermost axle.

The back elevation shows the interior of the body. Two pieces of wood may also be perceived under the body, which are united by other cross pieces, and thus form a small frame, which, by means of iron rings b and b'', is united to both axles.

The dotted line in the "Plan of the frame" shows the dimensions of the body; the small frame, $b\ b'\ b'\ b'$, which unites the axles, is also seen.

No. 5.

Wooden wagon employed on the lines of the Rouen and the Havre. The wheels are arranged with a frame formed with a chamfered end, upon which the body abuts in tipping. We have represented the wagon tipping, with the wheel upon the same horizontal plane; they, however, generally fall to a lower level, and do not tip upon the axles like the others.

In the usual plan of earthwork, these wagons are brought forward one after another at the usual pace of the horse, which is about four or five metres (13 feet to 16 feet 5 inches) in advance of them. The draw-rope is attached to the wagons by a particular kind of fastening, which unhooks itself immediately upon the man who conducts it drawing a string. The wagon then runs by itself towards the battery head, where it tips.

Plate 49.

Details of Wagons for executing Earthwork, Northern Railway.

These comprise the wheels which are formed out of a single piece, and the axles. The "small bolt" at $a\,a'$ in the end elevation, forms the hinge of the flap, No. 1, in last plate, and passes through the strap (4), shown below it. The "cast-iron carriage" bears nearly all the weight of the wagon when loaded, and upon which it tips: it is also shown over the "bearer for flap." The "flaps,

&c." (4, 5) show the ironwork and hinges. The flaps are closed by hooks at the corners a''' and d'''. The "grease boxes" (6) are those of No. 2 of last plate. "Grease boxes" (7) are at f of the same wagon. Those of No. 1 are similar. The small shield shown at the top is placed at $g\,g$. The rod at $p\,p'$, in No. 2, last plate, unites the wheels. $i\,i$ are pieces of square iron, and $j\,j'$ iron straps. The irons connected with the flap (g) prevent the wagon tipping.

Plate 50.

Railway Crab for moving the Bodies of Carriages. Invented by M. Arnoux.

This crane consists of an elevated stage, A, B, C, D, E, F, with a railway fixed upon it, m, n, o, p, and a car marked O, P, in the elevation, and L, O, P, in the plan, which is placed upon the rails.

The car carries all the apparatus required in raising the bodies from the carriages R, S. It is put in motion upon the railway by means of a winch handle, and a number of cog-wheels V, Y, and a tight-stretched chain Z, X.

When a body, placed upon one of the railway carriages, requires to be transferred to the frame of an ordinary carriage, the motive car is placed above the carriage, as shown in the Plate.

The apparatus for raising the bodies consists of a windlass, a break acting upon the same, a number of cog-wheels of different diameters, and chains which revolve in an opposite direction upon the windlass, passing over the pulleys (p and p' in the elevation, or $p\ p'\ p''$ and p''' on the plan). Round iron suspension-rods are fixed at the extremities of these chains, which pass through holes left in the small iron hangers s and s', supporting the body of the carriage, and which are properly keyed up at their extremities. The body is thus suspended to the rods, and may therefore be turned by the aid of the handle and the cogs of the windlass in either direction. It may also be raised or lowered as required.

Upon the body being raised, as shown in the Plate, the motive car is moved upon the railway with its load until it is situated over the ordinary road carriage, when it is lowered by means of the windlass. The keys of the suspending rods are then withdrawn, when the body is conveyed away on the carriage by horses.

The body of a diligence is transferred to a railway carriage-frame by a reverse operation. It is easy to perceive that the action of the handle turns the small wheel which operates upon the chain Z, X, and the movement of the carriage upon m, n, and o, p, is effected.

The wagon for carrying the bodies is also the invention of M. Arnoux.

Plates 51, 52, 53, 54, 55, & 56.

Manchester, Sheffield, and Lincolnshire Railway.—Details of Gorton Depôt.

Gorton depôt is about two miles from Manchester, and is intended to accommodate the locomotive works of the line. It is so arranged, that the capacity of the works can, if necessary, be doubled at any time without interfering with the arrangements. The principal novelty connected with it is the construction of the rotunda for the engines, the roof of which is supported by a single pillar, round which a circular turn-table revolves, thus providing standing room for a much larger number of engines than could be placed in the shed upon the old plan.

The plot of ground upon which the depôt is built, besides affording the requisite accommodation for the works, includes sites for 140 cottages, a house for the locomotive engineer, and spacious wharfage adjoining the canal, for the stowage of iron, timber, &c., for the use of the depôt.

The experience of previous companies has been carefully collected in preparing the plans, and every provision has been made for the future extension which these works invariably require, without in any way interfering with the simple and comprehensive arrangement of the plan.

This depôt has been designed under the direction of A. S. Jee, Esq., the engineer of the company, by Messrs. Weightman and Hadfield, architects, of Sheffield, the plan being arranged upon the suggestion of Mr. Peacock, the company's intelligent locomotive engineer.

Plate 51. Plan and Elevations of Depôt.

„ 52. Details of Engine-house: Ground Plan, Elevation, and Cornice enlarged.

„ 53. Details of Engine-house: Plan of Iron Principals, Section, and Details of Roof.

„ 54. Details of Fitting-shop: Smith's-shop, &c.; Section on the Line A——B on the Plan, and Elevation.

„ 55. Details of Workshops: Plans and Transverse Sections; Details of Roof, Floors, Columns, &c.

„ 56. Details of Store-sheds for Carriages: Plans, Elevations, Sections, and Details of Roof.

Plate 57.

Designs of Bridge proposed to be erected over the River Clyde at Glasgow, on the ground of Hutchison Hospital.

(John Rennie, Esq., F.R.S., Engineer.)

Hutchison Bridge was completed in the year 1833, under the direction of Mr. Stevenson, but the Trustees of the Hospital availed themselves of the professional services of the late John Rennie, in the design, as will appear by this Plate, which was engraved from the original drawing by that celebrated engineer.

Upon reference, it will be found that the present bridge is executed of the same proportions as the stone one shown in Mr. Rennie's drawing. Such is the matchless beauty of each design, shown in this plate, that the selection must have been a matter of some difficulty for the Trustees.

Plate 58.

West Durham Railway.—Bridge over the River Wear, Willington.

This bridge was erected in the years 1838 and 1839. It was originally intended to have been executed with stone arches, but as the line of the railway came so close upon the level of the river (24 feet at one end, and only 18 at the other, being an inclination of 1 in 28), the water-way would have been so contracted that it became self-evident that a stone bridge was not suitable. The flood-line being only 12 feet 6 inches above the summer water, the first high one would in all probability have effectually filled the arches and carried them away. It was therefore determined to erect a bridge with a flat platform, so as to interfere with the water-way as little as possible.

The bridge has two abutments, with a stone pier in the middle of the river, 7 feet thick. Both the abutments and the piers are supported entirely upon piles 21 feet long, which pass through the soft clay into the strong. There is an occupation arch, 12 feet wide, in one of the abutments. The superstructure consists of timber, with four sets of rails laid down upon it, the width of the platform being 43 feet, and which is divided into two compartments (see Plan), by the ribs supporting the roadway.

The spans of the arches are 79 feet, and the ribs one plank only in width (11 inches by 3 inches), with nine in depth. There are two longitudinal tie beams, 13 inches by 10 inches, beneath each rib, which are supported by queen

posts and iron bars, as shown on the drawing. The ironbars are four in number, and 1¼ inches diameter; and the posts (four in number) are 13 inches by 10 inches, and strapped and keyed to the ribs and beams. The two struts are 13 inches by 6½ inches. Corbels of the same scantling as the longitudinal beams extend underneath them to about 17 feet on each side, from the masonry, which add to the stiffness. They are all strapped to the beams, and keyed together to the ribs.

The deals of the ribs, as in other examples of laminated timber bridges, by Messrs. Green, are inserted into cast-iron springing plates, which are bolted to the ends of the beams. The joists of the platforms are 13 inches by 6½ inches, laid 4 feet apart, without any trussing between them.

The total actual cost of this bridge was:—

Masonry, including piling and foundations	£2438
Carpentry	1218
	£3656
And for the oblique arch, with the additional length of the walls and abutments entailed thereon	200
Total cost	£3856

Plate 59.

Namur and Liege Railway.—Bridge over the River Meuse, near the valley of St. Lambert.

Plans, Elevations, and Sections.

Plate 60.

Namur and Liege Railway.—Bridge over the River Meuse.

Details of Construction, Elevation of centre for Arch, Plan and Section of Coffer Dam.

Plate 61.

*The Great Wairarapa Road, New Zealand.—Bridge, over the River Hutt.**

Plan, Elevation, and Sections.

* This bridge was not erected at the time the author left the colony, but a pile bridge, of three arches, was thrown across the river, as sufficient for present purposes.

Plate 62.

Sheffield and Manchester Railway.—Dinting Vale Viaduct.

Plan and Elevation, and Details of Construction.

The laminated deal principle was first applied, on a great scale, by Messrs. J. and B. Green, of Newcastle-upon-Tyne, in 1834, on the line of the Newcastle and North Shields Railway, at the Ouse-burn and Willington Dean. The former is 918 feet long, and 108 feet high, with stone piers and abutments, and five laminated deal arches, three of 116 feet span, and two of 114 feet. The Willington Dean is 1050 feet long and 82 feet high, with seven deal arches. Five of 120 feet span, and two of 115 feet span each.

The timber arches of the Dinting Vale Viaduct consist of five arches each, of 125 feet span, and the laminated model is carried out very successfully.

Plate 63.

Sheffield and Manchester Railway.—Dinting Vale Viaduct.

Longitudinal Section and Details of Construction.

Plate 64.

Sheffield and Manchester Railway.—Dinting Vale Viaduct.

Transverse and Longitudinal Sections.

Plate 65.

Manchester, Leeds, and Liverpool Railway.

Details of Principle for centre Roof at Hunt's Bank Station.

Plate 66.

Manchester, Leeds, and Liverpool Railway.

Details of Principles for Side Roofs at Hunt's Bank Station.

Plate 67.

Manchester, Leeds and Liverpool Railway.

Details of Principles for Side Roofs at Hunt's Bank Station.

Plate 68.

London and Birmingham Railway.—Bridge for Road to Wing.

Elevation, Plans, and Sections, Details of Girders, &c.

Plate 69.

London and Birmingham Railway.

Details of cast-iron Syphon Culvert, and of a double Six-feet Culvert.

T. C. Savill, Printer, 4, Chandos-street, Covent-garden.

FOURTH SERIES

OF

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A Collection

OF

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WATER-WORKS, GAS-WORKS, WATER-WHEELS, MILLS, ENGINES,
&c. &c.

BY

S. C. BREES, C.E.

LATE PRINCIPAL ENGINEER AND SURVEYOR TO THE NEW ZEALAND COMPANY,
FROM THE YEAR 1842 TO 1845;
AUTHOR OF "GLOSSARY OF TERMS USED IN CIVIL ENGINEERING," "PRESENT PRACTICE OF SURVEYING AND LEVELLING," ETC.

LONDON:
JOHN WILLIAMS AND CO.
141, STRAND, (LATE CADELL'S.)
1847.

PREFACE.

THE present volume principally illustrates Railway Depots, Stations, Carriages,* Wagons, Trucks, Water Cranes, and the other contrivances connected with Stations. Like the "Third Series of Railway Practice," it consists principally of a translation from the "*Portefeuille de l'Ingenieur des Chemins de Fer, par* M. AUGUSTE PERDONNET, *formerly a pupil of the Polytechnic School, Professor at the Central School of Arts and Manufactures, and Engineer in Chief to several Railways; and* CAMILLE POLONCEAU, *Director of the Alsace Railway, formerly a pupil of the Central School of Arts and Manufactures.*"

It was the intention of the Editor to have carried the subject further, but he is compelled, by professional engagements, to bring it to a conclusion; and although it is not so complete as it might have been, had he been able to have devoted more time, still he is not without hope that the work will be found of some service to the English engineer.

43, *Lincoln's Inn Fields.*
20*th Sept.* 1847.

* See note on following page.

NOTE.

The Carriages constructing for the new lines in France differ very little from those used on the Rouen line.

Those built for the first and second class (January, 1846), on the Northern line, differ only in their dimensions, and the dispositions of the springs.

The bodies of the berlins or carriages are 1^{m} 75 (5 feet 9 inches) high in the inside, 2^{m} 40 (7 feet 10 inches) wide, and 5^{m} 46 (18 feet 9 inches) long. They are ventilated by small shutters.

The bodies of the second-class carriages, inside, are 1^{m} 75 (5 feet 9 inches) high, 2^{m} 30 (7 feet 6 inches) wide, and 5^{m} 45 (18 feet 9 inches) long.

Those of the third-class are covered, but are not enclosed at the sides, except by curtains, neither are they furnished.

The Engineer of the line from Avignon to Marseilles appears determined to use carriages with six wheels only, and states that they are better than those with four for great velocities.

They replace the brass of the chairs on many lines by an alloy forming an anti-friction metal composition.

INTRODUCTION.*

No work of any magnitude has at present appeared on the construction and materials of Railways, and what we now present to the public is not a treatise on the subject, since such a work would have exceeded our means.

The title of our work sufficiently explains the humbleness of our pretensions.

The "Engineer's Portfolio for Railways" consists simply of a selection of works, with notes, documents and plans, relative to the construction of Railways.

It will contain a few theoretical ideas, but many facts and calculations which may eventually serve as the basis of theory.

The subject of railways is of recent date in France. We were among the number of the first engineers who introduced them, and it is the result of some years' practice that we are about to offer to our companions, and those who intend to follow the same path. However insufficient or incomplete the information we are able to supply may be, however short our experience, we hope that the perusal of this work, and the study of the plates which accompany it, will not be altogether useless.

The works occurring in the construction of railways are divided into two great sections—Earthworks and Artificer's works.

We shall offer some general observations on earthworks† in the first parts of this work, and on the laying down of a railway; but shall not treat of artificer's works.

The material for railroads comprises the rails, chairs, sleepers, sidings, turn-tables, and different kinds of wagons, &c.

* This forms the Introduction in the "*Portefeuille de l'Ingénieur des Chemins de Fer.*"—Tr.

† M. Carl. Etzel, architect, formerly chief of the office on the Versailles Railway (left bank), has published notes on the execution of earthworks by means of railways, which he collected on the subject during a tour made by him through England by the command and at the expense of the Company of the left bank. Much useful information on the subject may be found in his work.

It has been our special endeavour to bring forward the best models of every kind of mechanism connected with railway works. We have introduced some which are now known to be defective, as we thought it necessary to notice them as experiments, if it were only to prevent their recurrence, rather than reject them entirely from our collection.

It does not comprise the locomotives. A description of the engines would require plans on too large a scale for the size of the portfolio, and a special treatise* would exceed the limits to which we have confined ourselves. Our object has been rather to study the other parts of the *material* and the arrangement of stations, a subject already sufficiently extensive and important to appear defective in a given case, and yet be admirably adapted for the purpose under different circumstances, or these imperfect plans may lead to real improvements.

The subjects represented in the plates of this portfolio may perhaps appear on too small a scale. Doubtless we have not always represented the subjects with as much clearness as we could have wished, but the numerous views with which almost all the figures are accompanied, will, in a great measure, remedy this inconvenience; and the smaller scale possesses the great advantage of comprising, in a small volume, a considerable mass of information.

The plans and sections of some of the subjects represented in the Portfolio, are sufficiently explicit to suffice for their execution in cases where a faithful copy might be desired. With respect to others, of which we have not been able to obtain the details complete, or otherwise have intentionally omitted parts, we may observe, that it is seldom an engineer requires to copy previous works exactly. A study of the plates will direct him to general principles and leading features to be attended to. He will find such a collection of plates in the Portfolio, as will conduce to his object, by affording him the means of comparing at a glance the different systems in practice. (See the Plates of Ballast Wagons, Passenger Carriages, &c.) When he afterwards wishes to complete his plans, he should examine the plates of details, among which he will find some of the best models, and if any blanks require filling up, his natural abilities, and practical experience, must supply him with the means.

A work of this nature affords great assistance to the engineer, but cannot exempt him altogether from labour.

* We have authorized M. Felix Mathias, Second Engineer of the Railway Works on the Versailles Line (left bank), formerly a pupil at the Central School, to take the plans of one of the best locomotive machines, purchased of Sharp and Roberts by the Company of the left bank. These plans will be published by him at Mathias' Library, on a large scale, and will be accompanied by an explanatory text and comparative detail.

It would have been impossible for us to furnish working draughts for each object, but we candidly state that, had all the necessary information been in our possession for such an object, we would not have done so, as it would have rendered the work excessively dear, and one of the principal conditions which it appeared to us necessary for the work to fulfil was, to come within the means of those for whom it is more particularly intended.

The work will not terminate with this volume, but we shall procure the drawings of new models, and publish them in the form of appendices. We shall also annex the necessary numerical information, and the various documents that may be collected.

The whole of the plates of the Portfolio have been executed under the direction of M. Felix Mathias, Second Engineer of the Railway Works on the Versailles Railway (line of the left bank). Many of the documents accompanying the text have been collected together by his exertions. We cannot bestow too much praise on the zeal, devotion, and ability with which he has so powerfully seconded us in this work.

Lastly, a public acknowledgment is due from us to the several scientific gentlemen who have assisted us—all of whom, without exception, have readily replied to the numerous questions we have addressed to them, and furnished us with valuable information:—To M. Masuy, Director General of the Construction of the Belgian Railways; to MM. Prisse and Mauss, Engineers of Bridges and Roads in the Belgian Service; to M. Bazaine, Engineer, who, with M. Chaperon, constructed the line from Strasbourg to Bâsle; to M. Clapeyron, Chief Engineer on the Railway from St. Germain's to Versailles (right bank); to M. Jullien, Chief Engineer of the Orleans Line; to M. Clarke, Engineer of the Works on the same Line; to MM. Didion and Talabot, Chief Engineers on the Railroad from Alais to Beaucaire; to M. Arnoux, Superintendent of the Workshop for the Manufacture and Repairing of the Conveyance Offices, Lafitte-Caillard; to M. Thebaudeau, Secretary of the Paris and Rouen Railway Company; and to M. Guillaume, Chief Superintendent of the Line from St. Stephen's to Lyons.

CHAPTER I.

ON THE DIFFERENT KINDS OF CARRIAGES AND WAGONS EMPLOYED ON RAILWAYS.

THE name of wagon is given to vehicles of every description employed on railways, and is adopted for carriages employed in the conveyance of passengers of the second class on the railways in the vicinity of Paris.

These vehicles differ essentially from those used on ordinary roads.

1st. They are always supported on four wheels, at least.

2ndly. The wheels are fixed to the axles, *which turn* in the boxes.

3rdly. The axles are always parallel.

It therefore results, that as they do not turn so easily as the vehicles on ordinary roads, they are not liable, as the latter would be, to get off the track, upon meeting with trifling obstacles. This mode of construction causes a considerable increase in the resistance at the passage of the curves.

The wagons differ from each other, according to the nature of the service for which they are intended, more especially in the shape of their bodies. There are:—

1st. Earth wagons.

2ndly. Ballast wagons.

3rdly. Passengers' carriages.

4thly. Carriages for the conveyance of letters, the sorting of which is performed in them.

5thly. Wagons for the transport of ordinary vehicles.

6thly. Do. for the transport of horses.

7thly. Do. do. cattle.

8thly. Do. do. goods of different kinds.

9thly. Do. do. sea coal, both *in the lump*, and small.

10thly and lastly. Wagons for the transport of timber of large size.

Sect. 1.—*Wagons for Earthworks.*

These wagons are employed for conveying the earth in the execution of embankments. The bodies are generally formed moveable upon an axis, so that they may be turned up either from the back, or on one side, when in use, like carts. A wagon which tilts up at one end, is called, *a wagon tilting on end*, or simply an *end wagon*. If it discharges at the side, it is known as a *side-tilting wagon*, or a *side wagon*.

Further, there are wagons which tip both at their sides and ends, whichever may be most convenient. The most simple method of constructing earth wagons, or, if we may use the expression, the most rustic mode is, in our opinion, the best.

If the earth wagons are too finely constructed, not only are they rendered costly, but their preservation at the yards is also rendered difficult and expensive.

The carpenter should be employed in the construction of this kind of wagon in preference to the carriage builder.

The capacity of earth wagons depends on the importance of the work for which they are intended, and the distances they are required to run.

It is necessary to make them more or less substantial, according to the time they are expected to be in use, and the nature of the work for which they are intended.

The Companies of the Versailles and St. Germains Railways, being obliged to procure wagons for their earthworks, adopted the form of those employed by the great English contractors in the execution of various important railway works. But since the former could not look forward to require them for the construction of other extensive lines, they have not, in our opinion, acted wisely in selecting such expensive models.

It was supposed that these wagons would afterwards serve for the ballasting required in the maintenance of the way, which was a mistake it is important that we should explain.

Ballast wagons require to be larger, and constructed with more care, than those for earthworks; and the bodies ought to be suspended, which is unnecessary with the latter.

Wagons which are drawn at a slow rate by horses, ought to be lighter than those conveyed at high velocities by locomotives. It would not, on the other hand, be prudent to use the lighter and weaker ones upon inclined planes, or where they would be exposed to violent shocks, or at the bottom of deep cuttings, since the earth is sometimes obliged to be thrown from a great height into the wagons. The loading of the wagons is often accomplished by workmen placed on

the road itself. It is necessary that the height of the wagon should not exceed 1^m 60 (5 feet 3 inches), so that men of low stature may not find any difficulty in this operation.

The total weight ought to be distributed as equally as possible upon the four wheels. That portion of the weight forming the body of the wagon, and placed at the side of the axle from which the wagon discharges, should not be formed so strong as that situated on the other side (See Plates 43 and 45, Third Series of Railway Practice), in order that the body may not be liable to continual oscillations during the progress of the wagon. It is, however, important that the difference in the load upon the two sides should not be considerable, by which the workmen employed in discharging may accomplish their work easily. The distribution should therefore be made accordingly in the loading.

The angle of tipping ought to be greater in proportion as the soil becomes bad, so that clay and wet soil may slide easily off the bottom of the wagon when discharged.

The wheels should be of sufficient diameter, so that the wagons may not be too difficult to move, and enabled to pass over any small stones or other substances which frequently obstruct the way.

Finally, it is necessary that the wagons be disposed so that the soil shall fall a certain distance from them.

The whole of these conditions in the construction of wagons for earthworks, are not fulfilled without some difficulty.

The wagons employed for earthwork on the London and Birmingham Railway, the Great Western, the St. Germains and Versailles Railway, (See Plates, 43 and 45, Third Series of Railway Practice) are all composed of two distinct parts.

1st. A *limber*, which comprises the wheels, axles, grease-boxes, and a framing resting on the latter.

2nd. A moveable body, turning on two chairs, supported by the frame.

The wheels of the English wagons are larger than the French, being 75 centimetres (2 feet 6 inches) in diameter, while the latter are only 50 centimetres (1 foot 8 inches). We have already alluded to the advantage of large wheels in facilitating motion; we must not, however, suppose that large wheels diminish the friction upon the gudgeon of the axles, since they require to be increased in diameter in the same degree as the wheels; the friction, therefore remains the same. It is the resistance at the circumference only that is diminished, which is of greater importance on a temporary way full of pebbles than on a permanent line in good con-

dition. We have also pointed out another advantage in large wheels—namely, that they may be employed upon the line itself upon its completion. This point, however, ought not to influence our choice of wheels much, since the largest that have been employed for earth-wagons are only 75 centimetres (2 feet 6 inches) in diameter, which is too small a size even for goods trucks, the wheels of which are seldom less than 90 centimetres to 1 metre (3 feet to 3 feet 3 inches) in diameter. They would answer better for coal wagons, but even in this case they would require to be bound with iron, if intended to run at great velocity. We consider that wheels formed altogether of cast-iron, like those used for the earth-wagons on the Birmingham and the Great Western Railways ought to be rejected for subsequent employment on the line. They are, moreover, in most instances, completely worn out after some months' use in the earthworks.

Smaller wheels have been adopted for the earth wagons on the lines in the vicinity of Paris than those used in England, on account of their being less expensive, and from their permitting the centre of gravity of the wagon falling down lower, which renders the working easier under the circumstances before enumerated.

The wheels of earth wagons, whatever their height may be, are always formed of cast iron in one piece. It is indispensable to cast them in a shell, forming a metal mould (*en coquille*) by which the periphery of the wheel undergoes a kind of tempering from being suddenly cooled by contact with the metal. There are certain openings formed in the nave, as shown in the plates of details, which enables the metal forming the nave and spokes to shrink and settle down without difficulty, since these parts take longer time in cooling than the circumference. The openings are afterwards filled up with iron wedges, and the nave is girdled when cold with an iron ring to enable it to resist the action of the wedging (see Plates). We have known instances of cast-iron wheels that have been neither formed *en coquille* nor girdled with iron, to wear out in a few weeks.

The axles ought to be made of wrought iron of the first quality, when they seldom break. The gudgeons on which the bearings and grease boxes are placed are the only parts that are turned. The usual dimensions may be seen by turning to Plates 44 and 47, "Third Series of Railway Practice." Referring to the fact that the gudgeons do not last long, but are invariably soon worn out from the action of the bearings, it would be better to increase their diameter, and the extra resistance which would consequently result would not be of much consequence in cases where the obstruction is principally found at the peripheries of the wheels.

The gudgeons are either placed outside the wheels, as in the French wagons, or inside, as in the English.

They are formed of less diameter, taking wheels of similar size when they are placed outside, as it renders them less liable to rupture, but the wagon is subjected to be upset by the axle breaking on the inside at the part near the nave; when these wheels are pushed laterally, or the flanges rubbed forcibly against the rails. In order to resist this kind of action, the gudgeons ought to be of greater thickness when placed inside.

The bearings and grease boxes of the earth wagons are generally very simple, the bearings are formed of one piece of cast iron, which is fixed directly on the side pieces by screws which also serve to support a small piece of wood, or a small plate of iron beneath the axle. The latter pieces prevent the body of the carriage from rising up and becoming separated from the frame by the effect of jolts, which are sometimes violent on roughly laid ways. It is essential that the screws should be thick and of good quality to resist the shocks arising from these jolts, also those which take place when the wagon is tilted and pulled up again by the frame in the operation of discharging the soil.

The bearings, or grease-boxes of the earth-wagons on the St. Germains Railway are very light and simple, but want strength at those parts where they are fixed to the lower side-pieces. The introduction of a brass bearing between the cast iron grease box and the wrought iron gudgeon of the axle, the same as with those used on the finished line, is unusual in wagons for earthwork. The surfaces in contact, therefore, consist of cast and of wrought iron. We consider that, notwithstanding the complication that would result from having a brass chair in the grease-box, that it would be very useful for earth-wagons.

It is of consequence to preserve the inside of the grease-boxes and their joints with the axles next the naves from the dirt, even of earth-wagons, with the greatest care, the wheels are for this purpose covered with a plank projecting over the lower side-pieces, and pieces of leather are nailed to the lower side-pieces over the grease-boxes.

The framework of earth-wagons is composed of long timbers, which form the lower side-pieces, of cross-pieces and bolts, for maintaining them at their proper distances, and of wood or iron diagonal pieces. The brackets supporting the tilting pivots of the body are placed on this frame, also those upon which the hinder part of the body rests.

In the different wagons shown in Plates 43 and 45, (" Third Series Railway Practice,") those of the Great Western excepted, the terminations of the lower

side-pieces form the touching points between the several wagons of the same train. These extremities are, for this reason, called the *butting ends*, or *butters*, and are securely bound with iron; the frame, therefore, being the part which receives the greatest shocks, consequently requires to be very strong.

The extremities of the upper longitudinal pieces of the body form the *butters* in the wagons of the Great Western Railway, from which we conceive that the body must undergo great wear.

The bolts which answer for the tilting pivot for the bodies of the wagons turn in cast iron boxes. These bolts are maintained on boxes in the wagons on the St. Germains line, and in some of those on the Versailles line (left bank) by iron stirrups, which are very expensive. The boxes adopted in the wagons of the Birmingham Railway are all formed of cast iron, and are much more economical. We have tried them, and found that they answered very well.

The bodies of earth-wagons are trapezoidal in shape, and a certain inclination is given to the sides to facilitate the tipping. The effect of the depth is diminished by extending the length and width; the inside is also made as plain and level as possible, and every projection is carefully avoided, as those occasioned by the heads of bolts and screws; the planks also forming the bottom are placed longwise. The angle of tilting is reduced, which facilitates the operation of the wagon greatly; it is, however, necessary that this angle should not be less than 40 to 45 degrees. Argillaceous soils are difficult to discharge under a less angle; and even under this, the workmen are sometimes obliged to detach it with pickaxes.

The bottom ought not to be formed of oak, but of deal, if not of poplar, and of sufficient thickness. The sides may be either of oak or deal.

The bottom also requires to be strongly supported, so as to withstand the effect of stones thrown in from a great height. It is with this view that the earth wagons on the Versailles (left line) have been formed with a special framework, which is not the case with those of the St. Germains. The employment of this frame has rendered it necessary to elevate the centre of gravity of the wagons. Therefore, in order to discharge them under the angle of 45 degrees, the two axles require to be loaded unequally, by which the hinder wheels jump up at the moment of tipping, and afterwards fall down on the rails. This *raising up* of the hinder wheels renders the discharge much more easy. The jolting has, however, on some occasions, caused the fracture of the grease boxes, although such accidents are rare.

We recommend, finally, that the transverse beams of the frame which, with

the longitudinal ones, support the body of the wagons, should be connected with a mortice, otherwise they run the risk of splitting upon the least shock.

The flap of the wagon, when placed at one of the extremities, may be raised like those of ordinary carts, which method is simple, and permits of the centre of gravity of the wagon being lowered, and of the angle of tipping being increased, and the discharge regulated accordingly. Or the flaps may be fixed to the bodies by hinges, as in the different wagons shown in the Plates 43 and 45, (" Third Series of Railway Practice.") The two iron arcs (see Plates), placed upon each side of the body, serve sometimes to keep the flap shut, and at others to sustain it while open in any particular position. The arcs of the wagons used on the Versailles line (left bank), and those of the St. Germains Railway are disposed so that upon the flaps being opened, they lie on the same plane as the floor of the wagon, which may be said to be prolonged. The earth is thus thrown some distance from the wagons. This advantage is lost with the English wagons, as the flaps hang down vertically. The inclination of the body when tilted is also obliged to be diminished, or the wagon lifted up in the operation of tilting, in order to prevent the flap striking against the rails.

It is essential to provide means, in the arrangement of the hinges, to prevent the earth which adheres to the flap from falling in the joint, and thus impeding the play of the hinge. The flaps ought to be made of one piece, and require to be very strong.

All the straps should be made of convenient dimensions, and of iron of good quality. The dimensions of the straps of the earth-wagons used on the Versailles line (left bank), and represented in the plates, are found from experience to be the most suitable. A description of the most approved forms will be found in the documents at page 149 of the " Third Series of Railway Practice."

The chain straps to the flaps which are employed to unite the body to the frame during the transit, are subjected to the greatest strain, more especially when the bodies are too heavily laden in front. It is, therefore, necessary to take particular precautions in manufacturing them.

It is not merely requisite to avoid all unnecessary expense in the construction of earth-wagons, but to make them upon such a plan as shall reduce the repairs to a *minimum*. One of the best means of effecting this is to provide all the wood of the same dimensions, and to manufacture the whole of the ironwork of the same forms and sizes, so that the pieces forming one wagon may be brought into use for the repairs of another; even the holes in these straps ought to be of a uniform

size, in order that when one strap is replaced by another, it may be unnecessary to cut the wood, or reduce its solidity. It is very important that the worm of the nut should also be of the same dimensions, and the bolts ought to be terminated by the same thread, so that every screw which is lost may be replaced by one of the same order.

The bodies rest immediately on the axles, in the earth-wagons employed on the Rouen line, shown in Plate 48, ("Third Series of Railway Practice.") This wagon is very simple in its construction, and of moderate height; but the mode of construction is only applicable for wagons that are discharged from their fore-end.

All earth-wagons ought to be provided with a break, more especially if they are employed on steep inclines. The Plates 43 and 45 ("Third Series of Railway Practice") represent breaks of different models, which are very simple and serviceable.

The breaks of the English wagons (Plate 45), have the advantage over the French (Plate 43), by acting on two wheels at once; but we may remark that it is impossible to use them with wheels of smaller diameter, if the same interspace between the axles be preserved. The lever of the break in the French wagons is nearly horizontal, so that the breaksman, who generally stands upright on the lower side-pieces of the wagon, gets on this lever in working the break.

The relative number of front tilting and side tilting wagons employed depends upon the necessities of the work being executed; it varies as the earthwork advances, one portion of the work would necessarily be standing still if wagons tilting at the end were exclusively employed, or others tilting only at the side.

We must further arrange to have a certain number of wagons capable of tilting both at the front and at the side, as those shown in No. 3, Plate 43 (Third Series of Railway Practice), and described in the text.

We entrusted the execution of the carpenters' work on the Versailles line (left bank) to one contractor, and confided the straps to another, the former fixing the ironwork and putting them together. It would have been better to have left the entire construction of the wagons to the same contractor, by which we should have avoided the difficulties which almost inevitably arise when the responsibility is divided between two different parties.

We find by turning to page 147 of the Documents ("Third Series of Railway Practice,") that the wagons discharging in front on the Versailles line (left bank)

cost 640 francs 65 cents. (25*l.* 13*s.* 6*d.*), and those at the side cost 664 francs 80 cents. (26*l.* 11*s.* 1*d.*) They were constructed of great strength, since they were intended to be drawn by locomotives at great speed. They might, however, be provided at a less cost at the present time. Wagons drawn by horses to short distances ought not to cost more than 300 to 400 francs. (12 to 16*l.*)

Those employed on the line from Lille, on the Belgian frontier, according to M. Brabant, cost only 450 francs. (18*l.*) (See the Documents in the "Third Series of Railway Practice.")

The wagons adopted on the line from Strasbourg to Basle are similar to those of the Versailles line (left bank), and an English model is employed on that from Alais to Beaucaire.

SECT. II.—*Ballast Wagons.*

We are now about to allude to one of the most important branches (practically speaking) in the construction of railways—the establishment of the permanent *material* (stock or plant)—which has hitherto been too much neglected.

The permanent *material* generally occupies the last place in our consideration: not until the whole of the other designs are determined upon, and partly executed, and the engineers are engaged in attending to the works in active progress, and have but little leisure, that it is thought of; when, in short, the subscribed capital, which is too often founded on erroneous data, is nearly exhausted, and economy has become a matter of necessity in all branches of the service. The consequence is, that the plant is not sufficiently studied, and the contractors are rarely allowed sufficient time to make their arrangements, to dry their timber, and to set to work carefully, whereby the company loses the right of expecting him to fulfil his engagement properly.

The choice and proper condition of the *permanent material* of a railway is of great importance, since the cost of maintenance constitutes one of the principal branches of the expense, after the opening of a line. When the material is badly constructed and defective, an expense, moreover, is incurred, not only in the additional cost of maintenance, but also in that of the conveyance which it involves. The difficulties which take place in the work render repairs frequently necessary, and are additional sources of expense, as well as of accidents, and also necessitate the maintenance of a large reserve stock of material, which is the same as sinking so much capital. When, on the contrary, the material is strong and properly arranged, this reserve may be greatly reduced. The fact of the amount required during the construction being less, is not the only advantage, since expe-

rience alone can expose the defects in the material, and we are enabled to take advantage of this experience, as well as of the improvements which every day arise, by not keeping a large stock, but obtaining it merely in proportion to our immediate wants.

When the designs for the material are determined, the companies execute it either on their own premises or let the work to contractors.

This latter plan is, without doubt, preferable, especially where a company has to collect proper workmen together, and to build the workshops in a limited period, while occupied with other important works. It is, moreover, the interest of a company to employ a contractor, even for the following reason only—viz., that of being able to impose a pecuniary responsibility upon him, which they cannot do with their workmen. There appear to be some reasons for abandoning this plan at a subsequent period, when the railway is in full working condition; but we believe they are not sufficient to induce a company to renounce the advantages which they obtain by employing a contractor.

The preceding observations upon the *material* (stock or *plant*) appeared to us necessary as a preliminary to the technical details which we shall now enter upon.

The wagons composing the permanent stock of a railway adapted to afford a rapid transit differ essentially from the wagons used in earthwork, and from all those used on temporary railways, inasmuch as—

1stly. The wheels are always from 90 centimetres to 1 metre (from 3 feet to 3 feet 3 inches) in diameter.

2ndly. All the wheels are bound with wrought iron.

3rdly. The naves of the wheels are always formed of cast iron; the spokes, with a portion of the circumference upon which the exterior tire and flange is fixed generally consist of wrought iron. The spokes of wagons used for goods only are, however, sometimes run in cast iron, together with the mould.

4thly. The cast-iron grease boxes resting on the gudgeons of the axles are always furnished with brass bearings.

5thly. The frame supporting the body of the wagon, or in some cases a platform, instead of a body, is borne on the extremities of the springs, which again rest (at the middle) on the grease boxes, and are fastened to the same by iron straps, as the ordinary carriage, represented in Plate 12, or the frame is suspended at the ends of the springs, as the carriage "*de luxe*," on the same plate. The springs are in this case separated from the grease boxes by frame-work, and do not, therefore, rest immediately on them. They are encompassed in the middle

by a stirrup, the pin of which passes through the frame and rests on the middle of the grease box.

The springs are frequently placed under the frame, as in the carriages on the Rouen line, and the frame is suspended at the ends of the springs by leather straps, as shown by the figs. in Plate 20.

The grease boxes are, in all cases, placed between two cheeks, formed either of wrought-iron, or of cast-iron of greater thickness, which are called *guard-plates*. They are fixed solidly to the frame, so that the grease box can move up when the spring is raised, and afterwards slip down again, but cannot be displaced laterally unless the plate is dragged away with the frame-work attached to it. The distance between the axles remains constantly the same, on the greater part of the lines in the environs of Paris—the grease boxes being effectually confined within the cheeks of the guard-plates; they cannot, at least, get displaced beyond certain limits, which may be determined at pleasure thus—a certain space is left for play in the carriages employed on the Rouen line between the grease box and the cheeks.

The number of the axles varies from four to eight. In the eight-wheel carriages those of each pair only (consisting of four wheels) are parallel, while in the six-wheel the three axles are generally so. This rule is, however, departed from on the St. Stephen's line (see page 19), where they are rendered moveable.

We shall hereafter examine into the advantages and inconveniences which the use of a greater or lesser number of wheels present, in treating of the bodies of carriages and their proportions.

6thly. The gudgeons of the axles are almost always placed outside the wheels. We may remember that this disposition allows of their being diminished in diameter (see page 13), and consequently of the resistance being reduced.

7thly, and finally, the frame-work of the wagons composing the permanent stock, carries springs, with some few exceptions (with goods wagons), to soften the shocks and jolts arising from the reaction of the different carriages of a train against each other.

We will therefore examine successively the different parts forming the permanent stock of railways, commencing with wheels.

Wheels are employed formed entirely of cast-iron, or of cast-iron with wrought-iron tires, or the nave only consists of cast-iron, and the other parts of wrought-iron. Wheels have also been used for locomotives with cast-iron naves, wooden spokes, cast-iron peripheries, and wrought-iron tires; but this description of wheel has since been abandoned.

Wheels formed entirely of cast-iron have not to our knowledge been employed

on any European railway traversed at great velocity, excepting the St. Stephen's and Lyons.

" Wrought-iron wheels," says Mr. Lockart, engineer of this line, in a *Memoire* published in the *Annals of Bridges and Roads*,* " are employed on almost all railways for the carriages and tenders; but when a railway presents inclined planes of some extent—such as that of 'Rive-de-Gier,' for instance—on the St. Stephen's, the fall of which is 1 in 17 for a length of 21 kilometres (about 13 miles), it is imperative to substitute cast-iron wheels. This is rendered necessary by the employment of breaks, which are used every minute, either to moderate the speed or to stop the trains near the stations. This frequent use of the break consequently reduces the period of service of the iron wheels, and renders their peripheries constantly irregular, which produces continual joltings, and proves most inconvenient to the passengers, which is independent of the serious inconveniences already stated in the paragraph relative to the fracturing of rails. An axle furnished with two wrought-iron wheels costs 435 francs, while it does not exceed 375 francs with cast-iron wheels. This great difference justifies the preference which is given to cast-iron wheels for wagons employed in the transport of coal on all the English railways. It is, therefore, advantageous to employ cast-iron wheels on railways presenting long inclined planes, and on which the traffic consists principally of very heavy articles, such as stone, coal, and minerals. These wheels, however, often break, and occasion accidents which somewhat detract from the advantages which they present in price, although we can meet this objection by stating that the plan hitherto followed in their construction is far from effecting the most favourable condition. It is, in our opinion, susceptible of most important improvements. Further, in order to give an idea of the durability of cast-iron wheels, we will instance some facts. The proportion of wheels broken or worn out is 40 per cent. on the St. Stephen's Railway, while on the line from Stanhope to Tyne, which is situated, as near as possible, in the same circumstances, this proportion (regard being paid to the difference in transport) is only 11½ per cent., and broken wheels are very rare on the latter; no more than three or four are broken annually, among 2000 wagons. This enormous difference is partly attributable to the superiority of the English castings over the French."

We have transcribed the preceding passage, as expressing the opinion of an able and practical man; we do not, however, agree with him in preferring wheels composed entirely of cast iron, even for lines presenting inclined planes of some

* **Annals of Bridges and Roads, May and June, 1843.**

extent; but we have not made any comparative experiments on the destructive action which the breaks exercise under the particular circumstances in which the St. Stephen's Railway is situated; but it appears difficult to believe that wheels furnished with wrought-iron tires and properly manufactured are incapable of offering the same resistance as wheels consisting entirely of cast iron. Moreover, as the latter are not turned like the former, nor are so correctly laid out from the centre, they cannot turn so well, and they proved defective even on the line above referred to, after a short time, since (from a letter addressed to us by one of the managers, M. Paul Seguin) wheels furnished with wrought tires have been substituted for the carriages, if not for the goods wagons.

All the wheels are bound with wrought iron, on the Croydon and many other English lines, where there are considerable inclines. In respect to the railways in the neighbourhood of Newcastle, where cast-iron wheels are adopted, we may state, that they all belong to that class of railways on which the speed rarely exceeds 4 or 5 leagues ($9\frac{3}{4}$ to $12\frac{1}{8}$ miles) per hour, and are intended more particularly for the transport of goods rather than passengers.

On all the great lines, where both goods and passengers are transported at great velocity by locomotives, the wheels are bound with wrought-iron tires, and even Mr. Lockart admits that they are preferable in these cases to those formed of cast iron.

Cast-iron wheels have been tried in America, according to M. Michel Chevalier, with wrought-iron tires united to the casting of the peripheries, forming one body with them, but which plan was obliged to be discontinued, as it rendered the milling work very difficult.

They generally place the passenger carriages on wheels formed with cast-iron naves and wrought-iron spokes, but wheels with both cast-iron naves and spokes are employed for the goods wagons. We advise the exclusive use of wheels formed with wrought-iron spokes for every kind of carriage or wagon used for passengers.

Wheels formed with cast-iron spokes are the cheapest, but the difference in price is not sufficient to compensate for their defects. They are also liable to accidents on account of their brittleness, which wrought iron spokes are not subject to.

In the event of a train running off the rails, or an axle breaking; if the wheels are formed with cast-iron spokes, they are exposed to fracture, while wrought-iron spokes would, on the contrary, be able to withstand the shock. These defects are too frequent with the former: a key fastened either too tight or too loosely, a tire too hot at the time of connecting it to the wheel, or too much

worn, or removed or replaced without sufficient precaution, form so many causes of rupture, either of which may occasion the entire destruction of the wheel. Wrought-iron spokes may therefore be considered superior, if it were merely on account of the strength which they afford the wheels; but this is not their only claim to the preference of engineers: they possess the quality of being also more elastic than those of cast-iron. We conceive that the employment of wheels constructed perfectly rigid would contribute powerfully to the destruction of the axle, since they would transmit the whole of the vibrations to it.

Wheels constructed with cast-iron spokes and wrought-iron tires are used for wagons employed in the transport of goods, and even for locomotives in America, being constructed after different plans.

The tire which receives the action of the rolling friction is formed of wrought-iron, and independent of the body of the wheel—the latter is not, therefore, cast *en coquille*, nor is the nave notched like the wheels of earth wagons. The spokes are then ribbed, as shown in the following cut, and the circular part is also formed with a rib upon the inside, or are double ribbed,

as the American locomotives, and fastened to the peripheries, like the wheels employed on the Belgian Railway, (see Plate 17); or, lastly, they are cast round and hollow, as employed in the goods wagons on the Birmingham line. (See wheels of the Alais and Beaucaire, in last plate.) Wheels with wrought-iron spokes are almost exclusively constructed as shown on this plate. (See the wheels of the London and Birmingham, No. 2; ditto, Orleans; ditto, Strasbourg and Basle.) The spokes are composed of strips of wrought-iron from eight to nine centimetres (3 inches to 3½ inches) wide, and from ten to fifteen centimetres (4 inches to 6 inches) in thickness, spread out so as to form triangles, with curvilinear, rectilinear, or pentagonal sides. The apex of each of these triangles or pentagons is lodged in the cast-iron nave, and one of the sides is supported either directly upon the outside tire, with the flange, or against the intermediate circle.

Wheels constructed with one circle are more economical than those formed with two, and last exceedingly well. They have been used on the whole of the English, on the Belgian Railways, and on the line from Strasbourg to Basle. The spokes of the wheel, No. 2, employed on the London and Birmingham Railway, (see plate,) are curved, in order to give them more elasticity. That of the Strasbourg and Baslé is the last model employed.

The Orleans wheel has been employed recently. The circles being more equally sustained than the others, the wheel will probably continue in wear longer

than the old ones. We, however, consider that further experience is required in order to become fully acquainted with their advantages.

Bramah's wheel has been employed on the line from London to Birmingham, and its construction is at once elegant and ingenious. Upon examining a transverse section of a spoke, we may perceive that it is composed of iron bars milled to a particular form and placed together; the wheel is bound with an iron circle, as shown, which is furnished with a tongue which fits into grooves formed in each of the bands forming the spokes. The tire upon which the flange is formed encases this band. Bramah's wheel, when thus constructed, possesses great elasticity, although it is expensive.

Hicks' wheel has not been much employed, excepting for a tender.

Lastly, we have seen wheels on the Great Western, the spokes of which were replaced by two cast-iron discs. These were both expensive in construction, and deficient in elasticity.

The shape and the dimensions of the tires are shown by the wheel on the London and Birmingham Railway, No. 2; ditto, Orleans; ditto Strasbourg and Bâsle, (on the last plate.) We recommend that they be made of sufficient thickness, in order to allow of being frequently turned during use, without becoming too reduced. The use of thick tires is, moreover, economical, since, being of some substance, they do not require so much labour in the construction.

Those used for carriages ought to be 35 to 40 millimetres (1·3 to 1·5 inch) thick in the thinnest part, in their rough state. The tires of locomotives are 45 to 51 millimetres (1·7 to 2 inches) thick.

It has been found necessary to increase the width of the tires on the English railways lately constructed, in order to give greater facility for lateral play, and to reduce the friction on the flanges. We may remark, that the width of the wheels of the last pattern employed on the Orleans line is 130 millimetres (5 inches), while those of the old-fashioned English wheels are 100 millimetres (4 inches).

The conicity, or inclination of the tire, varies according to the length of the radii forming the curves of the line on which they are intended to be employed. The inclination of the tires on the London and Birmingham Railway, where the curves are (with a single exception) 1000 metres (1093 yards) radius, is 1-13th, and on the Versailles line (left bank) the minimum radius being 1200 metres (1312 yards), the inclination is 1-12th. On the line from Strasbourg to Basle, where the curves are few but of great radius, it is 1-25th.

The edges or flanges of the wheels should be of great thickness, as well as the bodies of the tires, especially where the wheels are required to pass over curves

of small radius. It is essential to arrange so that the flange and body of the tire shall wear together.

The curved line uniting the flange to the periphery ought to be sufficiently long. It is, in fact, requisite, as the wheel becomes hollow in the middle, to leave a chamfer on the edge of the periphery, about one centimetre (·39 of an inch) wide (see cut).

Wrought-iron spokes being in general use at the present time, for wheels, it is proper to say a few words on their manufacture.

The bars forming the spokes of the wheel ought to be strengthened at their angles, as shown in Plate 17. The manufacture is commenced by the iron being doubled back, by which the thickness of the parts to be laminated is increased. They are afterwards placed in a cast-iron mould, and carefully curved, so as to give the concave portions a rounded angle, and an acute one to the exterior. The ends which enter the nave are cut off, as shown in the Strasbourg and Basle wheel.

The spokes thus disposed are placed in the mill, care being taken that the angles do not touch at their extremities: if this precaution is not taken, the subsequent contraction of the nave causes the casting to fasten them, so as to make them bulge out in the middle. They afterwards run the nave, leaving a good mass of metal at the top, and what is remarkable, running it into the mould as cool as possible.

It is advisable to cut off the extremities of the spokes which enter the nave; many wheels, however, in which this precaution has not been observed, have, notwithstanding, done excellent service.

The iron for the tire should present great hardness, and be capable of withstanding fracture. It ought neither to peel off nor split. These different conditions cannot be obtained without the greatest difficulty.

It has been endeavoured to manufacture the tires hard on the outside, and soft and tenacious within, but it rendered the bars liable to split concentrically upon the surface, the different qualities of the iron preventing the proper lamination of the whole. The wheels were consequently soon destroyed.

Upon the tires being curved, previously to being placed on the wheels, they are reheated in a furnace prepared for that purpose. Upon one or two heats being given, they are then curved on a mould either by means of vices, or by a cylinder, which is better, and which presses the tire against the mould, to which it is fastened by one of its extremities. Upon the tire being bent, it is welded together.

Formerly, when a tire was being welded, the extremities were sloped over each

other, and the edges bevelled off, which proceeding not only involved difficulties of execution on account of the great surface requisite to be welded, but in the managing of the piece. It also often altered the dimensions of the circle.

The following method is generally adopted at the present time: The two extremities of the tire are first sloped back, as at A and B, and are then brought near each other.

Fig. 1.

Two wedges, of the same thickness as the tire, are afterwards added at the forge, one of which becomes the flange. The tire and wedges are then heated separately, and when at the proper heat for welding, the latter are placed in the notches A and B, and hammered both horizontally and vertically, in order to ensure a perfect union of the whole. It is necessary that the two extremities of the tire should not touch each other, but the two wedges ought to do so. The tire being thus united without any alteration being made in its diameter, is again heated until red, and placed on a cast-iron mould to give it the requisite shape.

The moulds best adapted for wheels of one metre (3 feet 3 inches) diameter, consist of a simple cast-iron ring turned and divided into two parts, which is fixed against the tire by wedges. Moulds composed of several pieces are employed for wheels of greater diameter.

Fig. 2.

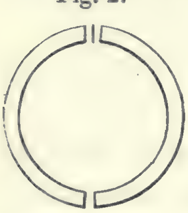
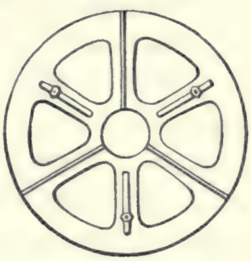


Fig. 3.



Moulds of the latter description are also used for small wheels, but the other model appears in this case preferable, on account of its extreme simplicity. A conical wedge is sunk into the centre of the mould, while the tire is being struck, in order that it should apply exactly upon the exterior periphery. This apparatus is placed on a large cast-iron frame, projecting all round, and requires to be solidly fixed. When the tire is moulded, it is immediately placed on the wheel, or, what is better, it is turned on the inside, and reheated. Upon these two operations being finished, it is then fixed on the wheel.

Tires which are not turned are very irregular in their shape, and adhere at certain parts only; they, consequently, deform the wheels. It is not only as well to turn them inside and outside, but also to prepare the exterior faces of the spokes with a coarse file. These precautions cannot be neglected with the wheels of locomotives, if they are dispensed with for wagons; otherwise they will last but little time.

The tire (together with the flange upon it) is fixed to the periphery by means of rivets (see Plate 17). It should be formed sufficiently conical to ensure of its being perfectly solid, and extended over the entire thickness of the wheel, and placed on with great care.

The use of screws is preferred on the Belgian Railways, which penetrate a certain distance only into the substance of the tire. A well-made wheel ought to sound like a bell, when the spokes are struck with an iron rod.

The breaking of an axle is much less dangerous than is generally supposed; they have been frequently broken, without causing any accident, on the lines from Strasbourg to Basle, and on most other railways. The bodies of the carriages being, as we may say, suspended one to another, are consequently guided and continued along the line, even in the event of an axle breaking.

Since, however, every means should be taken to prevent accidents, even those apparently the most improbable, and as the maintenance of the axles becomes expensive when they are badly manufactured, of inferior quality, or insufficient dimensions, we will, therefore, offer some remarks upon this subject.

Although the axles do not often cause accidents from breaking, the terrible and ever-to-be-deplored accident of the 8th of May shows us what may result from the axles of an engine breaking.

Plate 18 shows the form and dimensions of several axles, both of wagons and engines, and our observations upon them are the results of long experience.

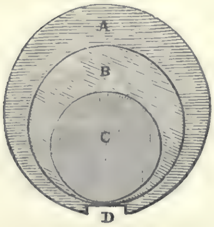
Axles seldom break, excepting at the interior part next the nave, from the effects of violent shocks and strains. It would be difficult to instance cases of axles breaking at other parts, excepting from some great defect. The whole of the efforts that the wheels are subjected to by the pressure of the flanges against the rails, and the vibrations in the substance of the axle, are transmitted to these points, independently of the direct action of the body of the carriage. As the former forms the greater strain, it is consequently important that the axle should possess greater resistance at these parts than at the others.

The axle was for a long time sloped off at an acute angle, precisely at its interior junction with the nave, as shown in the Axles of the Versailles and St. Germains, ditto London and Birmingham, No. 2; ditto Strasbourg and Basle (old pattern); ditto Paris and Rouen, (see Plate 18.) This may be readily perceived to have been erroneous, since iron is always more liable to fracture when in the shape of an acute angle. If an iron bar is struck with a tool formed with an edge in the form of an acute angle, it breaks at the first blow; but a round-edged instrument only bends it, several blows being required to effect a fracture, a fact well known to workmen. We may cite another example of the influence of acute

angles on the fragility of iron. The screws of the iron suspension-rods used on the railway from Strasbourg to Basle, which were acute angled, were found to resist very well while new, but broke off at the ends after a certain time. Upon being replaced by rods the screws of which were formed with rounded threads, the latter are found to resist much better, although of the same dimensions as the former.

The directors of the Strasbourg and Basle line, alarmed at the breaking of the several axles of the original model employed, (see Plate 18,) thought proper to replace the whole of them. Upon breaking them up, the examination of the fractures proved very interesting. The fracture always occurred at the inside, at the separation of the axle from the nave. It invariably appeared smooth and uniform, whether the axle was broken in the service or by blows of a rammer. The grain was very fine, like that of steel, in the zones A and B in the Cut.

Fig. 1.



It was coarser towards the zone C, until it became similar to that forming the body of the axle, where the iron had preserved its primitive texture. The brown colour of the rust in the zone A, like that of very old fractures, became gradually less in depth towards the zone B, and altogether disappeared in that of C. Lastly, the circles which surrounded the zones B and C, were not concentric, but all tangents to the circle representing the periphery of the axle at D, where the key was placed.

The same facts were observed in a great number of axles that had been long in use, and manufactured, moreover, of iron of totally different qualities—viz., of some of excellent quality, of very strong and homogeneous iron, and of that made with cast-iron cuttings, of iron of a scaly texture, and of iron breaking into large grains.

We see, from the preceding, how much use gradually modifies the axles; the oxidation of the fracture denotes the presence of a split, which gradually increases up to the moment of breaking. It appears incontestable that this kind of alteration results from the old method of cutting them off at an acute angle next the nave, but we must not altogether conclude that it would be effectually prevented by substituting a rounded contour instead. The axles which were originally executed with curves next the bearings on the line from Strasbourg to Basle have been broken with a rammer after three years' use, when they broke, at the extremities of their slopes, in the direction of A B. The fractures presented an appearance similar to the original axles. Those in which the iron was of good quality sustained

Fig. 2.

four blows of a rammer of 600 kilogrammes (1323 lbs.) dropped upon them from a height of 5 metres (16 feet 5 inches), sometimes upon one side, at other times on the other, before they broke.

The change in the texture of iron of which we have just spoken, has been noticed by practical men not only in similar cases, but also under circumstances perfectly analogous. Thus, two stone cylinders were employed to balance a draw-bridge at Toulon; these cylinders rolled on a curved road, and were united by an iron axle, the latter was made at the arsenal of chain cable iron, and participated in all the vibrations of the platform forming the bridge. After eighteen months' service, it broke on the passage of the mail (one of the horses being killed), and fell in several pieces, notwithstanding its excellent quality. The axis was re-established with iron of precisely similar quality, but covered with wood, which has since resisted perfectly well. The use of wood to destroy the vibration of the axles, and also to prevent their being affected, has also been recognised by the proprietors of public conveyances.

The following plan, founded on experiments made for the purpose on the line from Strasbourg to Basle, has been laid down, by which the construction has been improved. Their dimensions have been increased, especially at the parts next the wedges, and those portions which enter the nave and the body of the axle are connected by a conical shape necking, and the plane of the inside of the nave of the wheel corresponds to the upper projecting angle. (See the new pattern axle, Strasbourg and Basle Railway, Plate 18.)

The nave is bored so as always to rest exactly on the cone, and is driven by force upon the axle, so as to raze the iron a little. The wheel is fixed by three keys instead of one, which is not done for the purpose of securing the wheels in the centre (according to the original purpose of keys), but in order to prevent, as much as possible, any alteration of the axle, since this alteration, as we have shown, is less perceptible in the vicinity of the keys. When the wheel is once adjusted on the axle, one wedge is sufficient to maintain it in its proper position.

The gudgeons of the axles last referred to, are situated at some distance from the naves, and are of great length. These dimensions are rendered necessary by the mode of constructing the *material;* they would otherwise have been brought nearer the wheels, and not have been made more than 10 centimetres (4 inches) long. The gudgeons are 65 millimetres ($2\frac{1}{2}$ inches) in diameter. It is as well to keep them rather strong, in order to be able to place them on the lathe without inconvenience in case of necessity. Lastly, we remark that the brass bearings

do not wear out so rapidly when the collars of the gudgeons are made of great height, and the interior surface is made perfectly plane.

The new axles on the line from Strasbourg to Basle, are manufactured in layers composed of seven bars of flat iron, 27 millimetres (1 inch) in thickness. These bars ought to be thoroughly prepared by charcoal, and wrought with the hammer. The axle is always brought to the shape shown by the unfinished axle (Plate 18) by the hammer and without stamping. The manufacturers deliver them in this state at the workshops of the railway, where they are finished entirely cold, by which the iron is rendered perfectly homogeneous in quality, which would not be the case, if they were reheated; working them cold is, however, more expensive. If the axle was reheated at the extremities only, there would be an alteration in the texture even before the axles come into employment, precisely at the very points where it occurs slowest, from actual work and use.

It is customary for the whole of the axles, and some of the bars (at the least) intended to compose the axles, to be tested. The axles used for railway carriages are often tried like those for the artillery, either by placing them on supports set constantly to the same bearing, and dropping a rammer of a certain weight, and from a given height, upon each bar of iron, or by letting the bar itself fall horizontally upon metal blocks from a certain height. These tests are only tried upon a certain portion of each supply, taken at random, since they strain the axles greatly; and those which have been tested cannot be prudently made use of.

They proceed on a different plan on the line from Strasbourg to Basle, and on the St. Germains. Each axle is formed 20 to 30 centimetres (8 to 12 inches) longer than necessary. The ends are then marked off and cut to the proper length, when cold, in such a manner as to determine the position of the fracture, which is effected by a hammer. The total resistance of the iron is thus ascertained, and the quality and texture also tested and examined.

The fragments are marked with the name of the maker, and the number of the axle from which they were taken, and are preserved as proofs of the good quality of the iron employed, and for the purpose of ulterior observations.

The axles on the Strasbourg and Basle line, when manufactured in the manner above described, cost one franc eight centimes per kilogramme—the market price of the iron being 55 francs per 100 kilogrammes, at the works. The axle, when in an unfinished state, including the portions of the bar reserved for proof, weighs 156 kilogrammes (344 lbs.) The axles are covered with wood, previous to their being placed on the wagons, which, whatever its influence may be, cannot possibly do any harm.

The wheels being fixed on the axles, as we have before stated, by means of three keys, it is unnecessary, when they enter properly, to sustain them by very high shoulders, since they always become loose on the outside if they get unwedged.

The space required for play between the flange of the wheel and the rail, ought to be about three centimetres (one inch.) The tires should not be turned on the outside and laterally until the wheels are wedged on the axles.

The grease boxes rest upon the axles; their arrangement should therefore be considered immediately after the latter.

The friction at the circumference of the wheels does not appear to offer much resistance on railways in good condition, but it may become considerable on the gudgeons of the axles, unless reduced by lubricating the bearings, which requires to be performed with the greatest care. This also possesses the advantage of diminishing the expense of maintenance of the gudgeons considerably, together with the wagons.

Grease (properly so called) is employed for the axles of wagons on all the railroads that we have inspected, that from Lyons to St. Stephen alone excepted, where a kind of oil or very liquid grease is used.

There is a note in the Documents of the " Third Series of Railway Practice" on the different preparations of grease usually employed, to which the reader is referred. The composition varies according to the season of the year, so that it may always be sufficiently soft.

Mr. Lockhart, engineer of the St. Stephen's Railway, in the Memoire before cited, gives the following opinion on grease:—

" The system of greasing may thus influence the wear of the axles. This, with the system employed more particularly with carriages, consists of placing the grease sufficiently thick in a receptacle over the axle. The gudgeon is not greased until the friction has heated the apparatus sufficiently to make the grease run. It is therefore very evident that this heat cannot occur without injury to the axle, the surface of which must become affected by it.

" Taking this view of the subject, the plan employed on the St. Stephen's is much preferable. The grease, instead of having the consistence of a paste, is made very liquid; it is placed in a reservoir near the axle, and a small wooden cylinder within the former is forced into continual contact with the gudgeon by means of the springs; this cylinder being moved by the axle itself, maintains the grease constantly in contact with the gudgeon. The composition thus used in the place of grease costs only 14 francs per 100 kilogrammes."

The grease is contained in a kind of bason, or cavity, at the upper part of the

box over the axle in most of the railway carriages represented in the plates, and it drops from the bason on to the gudgeon through a cylindrical hole. The grease boxes are always formed on the same principle of construction, and merely differ in the form of some of their details. We have before stated that the grease boxes are formed entirely of cast-iron, with the exception of the bearings, which are of brass, and placed in the interior of the box, resting on the gudgeons of the axle.

They are each composed of two pieces of cast iron (see Plate 13), one of which is placed under the axle, and is of no essential use beyond preserving the wheel from the dust, and receiving the grease which drips, after having passed over the gudgeon.

The grease-boxes on the Belgian Railways (see Plate 14) are very simple in construction, but they do not prevent the dust introducing itself upon the gudgeons of the axle.

The greater part in use on the other railways are terminated on the inner side by a kind of ring furnished with a groove, in which there is a cast-iron disc. It is fastened to the nave of the wheel, and soon becomes covered with grease, and prevents the grains of sand raised by the wheel, as well as the dust, from entering the box. In order to appreciate the importance of this disc, it is sufficient to notice a train proceeding at great speed during the summer months; a cloud of dust is always raised, which covers the carriages to a certain height.

The joints of the grease-boxes are for the same purpose made in two places (see Plate 13).

The adjustment and mounting of the axles, grease-boxes, and guard-plates should occupy the whole of an engineer's attention. The diameters of the bearings ought to be a little larger than that of the gudgeons. The bearings require great care in the repairs, as they wear, in order to prevent the obstruction of the axle laterally, which would increase the friction considerably, and inevitably burn the boxes.

The grease boxes require to be solidly fixed, in order that, in the event of an axle breaking off flush with the nave, the wheels should be supported by the gudgeons, which being placed on the outside, remain attached to the box. The wheels resting firmly on the boxes might even support the weight of a locomotive for a certain time, and prevent a serious accident, unless it should occur under similar circumstances to that on the 8th of May, when the engine accidentally met with an obstruction; that presented by a level crossing, or a changing-place, would render a fall almost inevitable.

This condition is attained by making the whole of the several parts of the

grease-boxes, more especially the bolts, which fix it to the springs, sufficiently strong, in order to resist, not only the constant use, but also unforeseen shocks, and by shaping the lower part of the axle box so that it is retained by the collar of the axle, and cannot be separated from it. It is, therefore, erroneous to omit the lower part of the box, although often practised with locomotives.

In some of the wagons on the line from Strasbourg to Basle, the wheels would be supported, in case of the breaking of the axle next the nave—not only by the gudgeons, but more particularly by pieces fixed to the frame-work, which serve as guides.

We have stated that the grease boxes are sometimes set close between the cheeks of the guard-plates, and partake of vertical play only, others have a little play in the direction of the axle, and in that of the motion of the carriages.

This last arrangement facilitates the passage at the curves, and renders the motion of the carriages much easier. It has been tried on the Strasbourg and Basle line, and gave satisfaction. The following appears to be a remarkable result in these experiments:—

With straight lines and curves of great radius, (the frame work being suspended on springs, as shown in the third-class carriage, Plate 1, the wagon carefully mounted, and each pair of wheels perfectly equal in diameter;) the grease-box rested during the trip at the middle of the guard plate, without touching it.

The bearings of two wagons whose grease-boxes were mounted after this manner, were in fact soon worn unequally and destroyed, but we are not authorized in stating that this arose from the play of the boxes.

A trial of the same plan has also been made with locomotives, which led to the conclusion that this arrangement of the grease-boxes was very serviceable for them. It appears particularly advantageous, when the springs are suspended by leather straps in a position nearly horizontal; experience, however, on the Strasbourg and Basle line has proved that it succeeds with springs of other kinds.

The play at the diameter of the axle of the carriages on the Rouen line amounts to 6 millimetres (·23 of an inch) on each side, and 10 (·39 of an inch) vertically. When the grease-boxes only move in a vertical direction, it is necessary to leave some play for the axle laterally in the box, or in the direction of its length.

When a wagon is first brought into use, it is necessary frequently to inspect it, during the running and when at rest, to see that the boxes do not get heated, and that the grease runs well over every part. It is necessary to alter the position of the box until it ceases to heat. If the boxes become very hot, and the

gudgeons also contain brass incrustations, which is frequently the case, it is necessary to file them off, and to remove all inequalities, otherwise it continues to heat, and soon wears out the gudgeons and bearings, and lastly breaks and occasions accidents. When the gudgeons of new bearings heat slightly, it may be sometimes remedied by merely mixing flour of sulphur with the grease.

We must not content ourselves with inspecting the grease boxes externally. It is requisite to raise the bodies and framework every journey whenever the carriages have been in use four or five successive days, and examine the gudgeons, boxes, and bearings; and upon the expiration of a certain time, the cleaning must not be neglected. The best means of cleaning the boxes is to wash them in cold water, which dissolves the grease commonly employed upon them. If the boxes are only wiped, the sand will be always left upon the sides.

Upon the grease boxes ceasing to heat, it is necessary to keep them in a perfect state of order; the flaps which cover them should, for this purpose, be constantly closed; the men ought to be fined if they leave them open; it is also as well not to place fresh grease in the boxes without skimming off the top of that which remains in it at the time, and wiping the sides. There is some risk of introducing sand along with the grease into the box, unless this precaution is taken.

If these rules are strictly followed, the rolling is rendered very easy, the consumption of grease very slight, and the wear of the bearings almost nothing.

The consumption of grease, which amounted originally to 50 kilogrammes (110 lbs.) per day on the Versailles Railway (left branch), was in this way reduced to 8 kilogrammes (17 lbs.) per month for the daily use of 24 trains, consisting of about six carriages, each running about 17 kilometres ($10\frac{1}{2}$ miles.)

In an experiment made with the passenger carriage, it ran 28,470 kilometres (17,690 miles) without the bearings, which were four in number, losing any more than about a gramme (.0022 of a lb.) in weight.

Carriages which are run at great speed on a railway are generally suspended, but the mode of suspension is very rude. They are much inferior in this respect to ordinary carriages. The springs sometimes rest, as we have before stated, directly by their middle on the boxes; at other times, but more rarely, they are suspended. They have lately been made of great thickness, and with a very strong bend on the French railways, being placed directly beneath the lower side pieces.

The springs (to be well made) ought not in this case to be curved, excepting at the middle, and along more than a third of their entire length. They should be

nearly straight at their extremities, and terminate in one or two folds, the extremities of the lower one being only one-half the thickness of the upper. If these springs were made in the shape of a regular curve throughout their entire length, and the extremities composed of several leaves; they would bend in the middle, become too rigid, and would soon get out of shape.

The mode of suspension employed on the English lines of recent construction, and on the Rouen, is superior to that of the old French railways. The springs are almost straight, and much more elastic, and the leather straps situated at their extremities render their movements very easy. The springs employed on the Badois Railway are also very lightly sustained by leather straps.

Railway carriage springs ought not to be too slight, since they require to be capable of resisting fracture when a train is thrown off the line, and of preventing the danger of an accident.

We have not alluded at present to the conditions required in the manufacture of carriage springs, which are the same as those for ordinary carriages. The mode of testing consists simply of straightening them when cold by means of a press, and then leaving them. If they are of good quality, they will return to their original shape.

The guard plates in which the grease boxes play, are made indifferently either of cast or of wrought iron. The motive power which operates directly on the frames of the carriages, is transmitted to the grease boxes and to the axles through the medium of the guard plates, unless the grease boxes are not allowed to play, like those of the carriages on the Rouen line, and the oscillations of the axles from the movement of the pins act equally upon the guard plates by means of the boxes. It is, therefore, necessary that they should be very strongly fixed to the frame, in order that these guards should be able to resist, and that the distance of the grease box to the side pieces (which form the length of the lever at the extremity of which the motive force is communicated to the guard plate) should not be too long.

The first condition is attained by multiplying the bolts which fix the guard-plates to the frame, and arranging them suitably; and the second, by placing the springs above the frame, as in the "*carriage de luxe*" on the Versailles line (See Plate 12). It is accomplished in a great number of locomotives by placing it at the side of the frame, and suspending it, as in the Belgian carriages (Plate 5); or, lastly, by using flat springs, like those of the carriages on the Rouen line.

The number of bolts employed to fix a guard plate generally amounts to

four or five, forming two parallel ranges, and it is requisite that the bolts forming the lower line should be as far apart from each other as possible. The guard-plates, after being dressed and smoothed, should be bored with great care, and the entire length of the bolts turned, so that their diameters shall correspond exactly with the holes.

We have already alluded, in treating of grease-boxes, to the importance of placing the guard-plates with the utmost care, the mounting of which, we may say, determines the places of the grease-boxes and axles. When the grease-plates are placed badly, the resistance of the wagon is considerable, and the bearings, also the flanges of the wheels, are rapidly worn out.

It is not sufficient for the guard-plates to be merely well placed, and the axles parallel between them. It is most essential that they should be perpendicular to the axis of the figure of the frame, or the line of traction, and that the line forming the centre of each plate should be exactly on the same. This cannot be obtained unless each frame is set out *geometrically*. The use of a gauge only is insufficient to ensure these conditions.

When the guard plates are once secured to the frame, and it is ascertained that they are fixed with the requisite accuracy, the frame is mounted with the guard plates upon the springs, grease boxes, and axles; the bodies are then put on, and the wagons brought into use. It is essential to make frequent examinations for some time during service, to see that the guard plates are not deranged, for the wood of the frame nearly always works, in consequence of its exposure to the air, and from the effects of the load, when it becomes necessary to re-adjust the plates.

The interior surfaces of the guard plates are, in general, the only parts dressed, but it is better to dress both sides, since the grooves of the grease boxes rest against both edges.

The cheeks of the guard plates are always connected together beneath the grease boxes, as shown in the plates, the object of which is not only to increase the strength of the plate, but also to permit the body of the carriage being lifted up in case of an accident, and replaced again on the line without separating it from the axles.

It has been endeavoured to place the guard plates directly below the grease boxes, but they pressed so much against the latter as to break them.

The guard plates occurring on one side of a frame are often connected by long bolts, which arrangement maintains the distance of the axles, and enables the breaks to press the wheels on the inner side only.

Two guard plates are also often employed for each grease box, one upon each side of the side frame pieces, which are joined securely together by cast iron pieces, bolts, or rivets.

The frame, which either rests on the springs or is suspended from them, serves to support the bodies of the carriages.

The tractive force always acts directly on the extremities of the frames, or, rather, on the spring traction and buffing apparatus, which form a part of it.

If we examine the frames of carriages, we shall find considerable variations in the method of construction on different railways. They may be, however, all included under two heads: those consisting of double frames, such as the carriages of the London and Birmingham Railway (see second-class carriage, Plate 2), and the simple frame, like those of the ordinary carriages of the Versailles line (left bank), Plate 10.

The double frames consist of two pieces of wood, of slight thickness, and connected by iron work more or less complicated, the transverse beams being also situated between them. The ends of the springs of the traction and buffing apparatus are generally lodged in the space between the two frames, as in the carriages on the London and Birmingham Railway, and the *carriage de luxe* on the Versailles line (left bank), or the suspension springs are fixed there as in the carriages with four wheels on the Great Western Railway and the *carriage de luxe.*

The single frame appears to us preferable to the double one. It is much less expensive, as well as stronger, although doubtless more subject to derangement from the play of the wood, but this improves by use. The effects of this play are neutralized by a judicious system of carpentry, a good choice of timber, and by the application of iron work.

The bodies of the carriages rest immediately on the side pieces, when the double frames are used, the width being limited by the distance between the shaft pieces. When, on the contrary, the single frame is adopted, the bodies are supported on transverse timbers, which project over the side pieces; the former may consequently be made of any required width, which is an important advantage.

We may enumerate among the *double-framed* carriages:—

The carriages on the London and Birmingham Railway.

The four-wheel carriages on the Great Western.

The carriages on the Gloucester line.

The *carriage de luxe* of the Versailles line (left bank).

The original carriages employed on the Orleans line.

The old carriages on the St. Germains line.

And among the *single-framed* carriages:—

The third-class carriages of the Birmingham Railway.

The carriages with six wheels on the Great Western.

The carriages on the Versailles line (left bank).

The carriages of the Belgian lines, and those of the Strasbourg and Basle Railway.

The carriages used on the German Railway.

The carriages of the Rouen line.

The frame of the carriages of the London and Birmingham, shown in Plate 1, belonging to the class of double frames, would be deficient in strength without numerous iron contrivances to unite and consolidate it, the various parts being composed of pieces of wood of slight thickness. Thus, the two side pieces, placed on one side, are united by cross pieces, of the shape of a double T, and their extremities are tied to the transverse pieces by double squares.

The diagonal pieces are fixed both to the transverse pieces and to the shafts by means of squares, and the centre of the frame is secured by the ironwork which maintains and guides the springs. Lastly, the frame is covered beneath throughout its entire length, with a band of iron screwed to the shafts, and to the transverse pieces, in the direction of the diagonal pieces.

The springs employed to soften the shocks, and to answer the purposes of traction, are four in number—two for each.

This arrangement of the frame-work may be considered to be independent of, although intended for the support of the springs; the latter alone support the force of the action and reaction, both of that in the line of traction and that in the opposite direction. We may therefore consider the carriages forming a train composed of carriages constructed on this plan as attached simply to an extensive apparatus composed of springs.

The traction-springs being joined at their ends, press one against the other, so that they are able to resist the greatest force without the frame-work suffering; the same with the buffer springs, which rest against each other at the middle, where they are united by straps.

If we turn to Plate 16, in which we shall find the details of this traction and buffing apparatus, we may remark that the traction rods are formed with screws, in order to permit of the springs being stretched upon their elasticity being reduced by use. These rods are formed round throughout, excepting at the guide,

next the hook, where they are squared. They are gradually diminished as they leave the buffers: experience has shown, that the dimensions given in the plan cannot be departed from without inconvenience. The plate which supports the buffer is formed of wrought iron, and attached to the end of the rod by means of a rivet.

The buffers were originally formed of wood, and furnished with leather stuffing; these are now replaced by others formed entirely of wood, which are just as good, and cost less in maintenance. Wooden buffers require to be furnished with iron rings, to prevent their splitting.

The guard-plates are fixed to the lower side pieces by a kind of foot, through which the bolts securing them together pass, and to the upper side piece by a single bolt. The bolts being thus situated at some distance from each other, the plate is very strongly secured.

The space separating the guard-plates on one side, and consequently the distance between the axles, would appear to require to be equal to half the length of the carriage. It, however, usually exceeds this, since, when the axles are too close, the ends of the frame are badly supported, and soon become curved, which has been previously noticed.

The frame-work of the carriages on the London and Birmingham line, which we have just described, is extremely slight, but is notwithstanding sufficiently strong, although expensive, and, perhaps, somewhat deficient in stiffness.

The traction apparatus cannot be repaired with some carriages, or even a screw replaced, without taking up the body or end, or even undoing a part of the frame, whence great inconvenience results to the traffic and maintenance. The frames used on the London and Birmingham possess the advantage of admitting the pieces comprising it being taken on and off very easily.

The frames of the carriages of the second class on this line are exactly like those of the first, but formed of a less length.

The frames of carriages of the third class consist of one frame only; we shall therefore include them among the frames of the second kind, and which we shall subsequently describe.

The frames of the four-wheel carriages of the first class on the Great Western Railway, (see Plate 3) are, with respect to the carpentry, precisely similar to that of the London and Birmingham.

The traction and buffer springs are supported like the latter, by two transverse pieces, on which the diagonal pieces are secured, and by two pieces of wood resting on the transverse pieces h and h'. The arrangement of these springs is

sufficiently explained in the description of Plate 4, and in that of the details in Plate 21. It is much more simple than the system of springs connected with the double frame used on the London and Birmingham Railway, and answers the same end.

We find, in fact, that wagons constructed in this manner, and forming the same train, are united like those of the London and Birmingham line, by a kind of elastic chain, which serves as a perfect medium for moving the train, and at the same time diminishes the intensity of the shocks. Each frame is drawn from the centrè; the action is therefore transmitted from this point to the side pieces by means of the diagonals, and from the side pieces directly to the body, which they support, or indirectly, by the assistance of the guard-plates to the axles and wheels. Every piece in the frame is thus subjected to the action of a force, which is directed to such parts where the strength is greatest. The frame consequently sustains the slightest strain possible.

This traction and buffing apparatus has, however, been abandoned, on account of the points of fastening of the traction rods *o* and *o'* being too near the centre of gravity, from which it resulted that the vehicles partook of the movements of the pin too readily.

The suspension springs of the carriages on the Great Western, of which we have described the frame, are placed between two side pieces, and rested on the grease boxes, as shown in the plate by the intervention of a round rod or pin, which passes through the lower side shaft. The upper part is terminated by a strap, which embraces the springs. The same arrangement is followed in the "*Carriage de luxe*" of the Versailles line (left bank), and in a great number of locomotives.

The springs, in these cases, invariably preserve their position, provided the extremities are attached to moveable straps, which are capable of turning on the fixed points situated on the frame, or the vertical rods tied to the frame, as with locomotives. If, on the contrary, the extremities of the springs are free, the vertical rods supporting the middle of the spring are apt to become twisted. It is, therefore, absolutely necessary that the grease boxes should be properly guided, and the springs maintained by iron plates fixed on the sides of the frame to the two side pieces. We recommend the use of these plates, even when the arrangements of the springs may not require them, as they are very easily fixed, and the expense is trifling.

The centre of gravity of these carriages may be lowered by placing the springs between the two side pieces, instead of beneath the lower shafts, and the

length of the guard plates diminished. But the springs cannot, on the other hand, be allowed so much room for flexure, and the fixing also becomes very difficult.

The frames of the carriages of the first class on the Gloucester Railway, Plate 1, consist of a double frame, also those of the carriages on the line from London to Birmingham, and the frames of the four-wheel carriages on the Great Western Railway; but as the space between the side pieces of this frame is neither occupied by the extremities of the buffer springs, nor by those of suspension, there can be no other motive for the adoption of the double shaft in this instance, than the desire to render the frame lighter and of a more elegant appearance.

It is formed of shafts and transverse pieces, united by diagonals, and appears to us to be well calculated to resist every description of distortion arising from the play of the different pieces. The springs for the purposes of traction and for breaking the shocks are of the description called spiral springs. It is generally held that these do not preserve their elasticity so long as ordinary springs, and that they cannot sustain great strains. Spiral springs have, however, been tried on the line from Strasbourg to Basle, composed of a peculiar alloy, invented by a Mr. Klein, and which has given satisfaction.

These springs easily support a weight of 800 kilogrammes (1764 lbs.), but a weight of 1200 kilogrammes (2646 lbs.) bent every ring in each spiral, so that they were all brought in immediate contact with each other. Upon this weight being allowed to remain on them, and the springs left in this position for twenty-four hours, they returned to their original shape with a loss of no more than two millimetres (·0787 of an inch) in the line of their extension upon the weight being removed.

It is proposed to try springs formed of this composition (which appear to promise great advantages in certain cases) for wagons.

The frames of the carriages on the Gloucester Railway are not placed entirely above the suspension springs, like those of the carriages on the London and Birmingham, but are suspended to these springs by means of transverse pieces, so that the extremities of the springs are placed on the sides of the shafts. The springs also do not rest on the grease boxes, but pass beneath them. The frame, and consequently the bodies, of the carriages are therefore brought very near the ground.

It appears to us very convenient to lower the centre of gravity of the carriages generally, whatever means may be employed to accomplish this object.

Carriages of small height are more firm, and much more convenient in ser-

vice. The passengers are enabled to pass in and out readily at any part of the line, by which the construction of platforms at the stations is rendered unnecessary.

We must admit, that the mode of suspending the frames to the springs by transverse pieces, offers less solidity than suspending them from the side-pieces; but the difference is not, in point of fact, sufficiently great to exercise much influence in the cost of maintenance, in ordinary cases at least, when the suspension is effected, according to the plan of the carriages on the Gloucester line. It might, however, increase the danger in case of the carriage getting off the rails, or any other accident. We cannot insist too strongly on the necessity for making the whole of the several parts forming the frame (whatever purpose they may be intended for) sufficiently strong to support the violent shocks under the numerous circumstances to which the trains are exposed.

The frame-work of the "*carriage de luxe*" on the Versailles line (left bank) presents us with a third model of a double frame.

The pieces forming the braces of this frame are curved by the process of steam. There have been frames used on the same railway in which these pieces were straight, and notched out in the middle, where they crossed each other, like the frames of the German carriages (see Plate 24). They were rather less expensive than the former, and appeared to be sufficiently strong.

Frames formed with double diagonals, like those of the carriages on the Gloucester line, have also been advantageously employed. The frame of the "*carriage de luxe*," on the Versailles line (left bank) has no more than two springs, the middle of which receive the efforts of traction, and that exerted by the buffers acts on their extremities. This arrangement of the buffing and traction apparatus is very economical; but since the weight of the springs acts on the extremities, and tends to curve the frame in a vertical direction, it is necessary to place the axles wider apart than in the carriages of the London and Birmingham, and the efforts of traction and striking do not act ultimately on a system of springs, independently of the frame, whereby the latter becomes strained and displaced.

The suspension springs are placed between the two side-pieces, as in the carriages of the Great Western line, the advantages and inconveniences of which arrangement we have already pointed out.

The whole of the iron work of the frame we have just described is represented in Plate 13, the description of which will furnish the necessary explanations. A frame was adopted originally, on the Orleans Railway, similar in the whole of its construction, with this exception, the suspension springs, instead of being placed between the side pieces, were situated between the lower shafts.

This description of frame has been since abandoned on the Orleans Railway, also on that of the line of the left bank, and replaced by a single frame in which the buffing and traction apparatus rests on the middle part.

The frames used on the Belgian lines for carriages of the first, second, and third class, (see Plate 5,) are composed of four transverse and two side pieces, the latter resting on the former pieces, and being bolted thereon. The wheels are placed between the transverse pieces outside the shafts.

The bodies, having the lower parts formed of two independent frames (represented at Plate 5), rest upon the side shafts.

These frames, although making part of the bodies, may be considered as belonging equally to the limber or to its frame, for they are constantly attached together, and serve to guide the traction and buffing apparatus.

The guard plates represented in the Plate of Details (14) are placed outside the wheels from one transverse piece to the other, and are fixed to the same by square cheeks as shown in the plate.

The springs resting on the grease boxes, carry the frames which are suspended at their extremities by four transverse pieces.

The buffer and traction springs are placed at the extremity of the frame, the buffers being perpendicular with the shafts, and sliding together, with the ends of the springs between pieces of cast iron.

The frames of the carriages employed in Belgium present many serious inconveniences from not being tied by any oblique pieces; they consequently get out of shape, and the axles lose their parallelism sooner than others.

The side pieces rest on the transverse pieces at a sufficient distance from the extremities, and the springs, which serve to support the whole, are fixed at these parts. The weight tends to spread the transverse pieces, for we know that a piece of wood gradually yields under a weight, and although it be only slight, it forms another cause of the form of the frame altering, and the repairs are rendered difficult and consequently expensive, from the body being fixed to the frame.

In short, the traction and buffer springs being placed at the extremities of the frame, like those of the carriage frames on the Versailles line (left bank), present the same inconveniences. As they are, however, much lighter, the frame sustains less strain—so far, at least, as regards the action of the weight of the springs.

The frames of the carriages used in Germany, Plate 24, are very similar to the Belgian; they are, however, superior, inasmuch as they are secured strongly together by diagonal pieces.

The iron fastenings of the double frame of the carriages of the St. Germain's line, (Plate 7,) are much less in number than in that used on the London and Bir-

mingham. This frame is more simple in its construction, but, like the last, it is deficient in stiffness, for although the weight of the springs is placed in the middle, the extremities become curved. This alteration in the form arises equally from the circumstance that the axles are placed exactly beneath the centres of gravity of each half of the body. This arrangement, although theoretically the best, always occasions a sinking of the extremities of the carriage.

This system, like every other of the same kind, presents the inconvenience of requiring springs of great length, which are very heavy and expensive.

If we pass to the details of the construction, we find that the buffer rods are square, which form is not so good as the round ones, since their adjustment becomes both difficult and expensive.

Those of the carriages on the St. Germains line were constructed before sufficient experience had been gained, and are consequently of very weak dimensions.

The fastening of the springs to the buffer rods (Plate 8) is much more complicated. It is sufficient if the rod rests on the extremity of the spring, as in the carriage of the London and Birmingham line. The guard plates are too long and slender, and they are not fixed sufficiently secure to the shafts; the grease boxes are not conveniently guided; the grooves are too short, since they should rub throughout their entire height against the guard plates. They would have been prevented rubbing against the springs and straps, the friction of which soon wears and displaces them, had they been made longer.

The frames of wagons of the second class on the St. Germains line (Plate 7) differ essentially from those of the first. They are more simple, and had neither buffer nor traction springs originally, but experience soon led to their adoption.

This frame appears almost too strong, compared with those which we have previously described, notwithstanding which it gets curved; but we must explain that the axles of the second-class carriages, like those of the first, on the St. Germains line, are situated too close together, and the guard plates and grease boxes are consequently badly placed.

The frames of the carriages on the Versailles line (right bank) are, with some slight exceptions, very similar to those of the wagons of the second class on the St. Germains line; the difference consists in the plates, which are in the middle of the frame of the latter, being replaced in the carriages of the Versailles line by four transverse pieces, which serve to support the extremities of the buffing and traction springs (see Plate 8), and the centre piece is not prolonged on each side to the extremities of the transverse pieces, by which more room is made for the apparatus, of which the springs form the principal portion.

This system works well; but the weight of the springs, which are required to be four in number, acts very injuriously upon the ends of the frame, on which the tractive force consequently reacts, which the springs have to support. It moreover presents all the inconveniences in the use of one buffer, which defects we shall point out hereafter, in treating of the drawing apparatus.

The frames of the carriages of the left bank (Plate 10) are firmly secured, as we may perceive, by means of two strong side pieces, and by braces, consisting of two pieces bent by steam, which are fixed to the angles, and bolted in the middle to the centre beam (which does not extend along the entire length of the frame), and by five large transverse pieces which support the planking of the body at points very close together, and which serve at the same time as guides to the traction rods of the apparatus.

The use of bent pieces has been dispensed with, without suffering any inconvenience, in another model of this frame; also in a third (see Plate 10); both of which are described at page 33.

The system of tyeing has, moreover, been modified, which was before perfectly satisfactory. The cross braces met the side pieces in the original model at very acute angles, which has been remedied by substituting a double brace.

We refer the reader to the descriptions of the plates for an explanation of the buffing and drawing apparatus, which he may perceive is very simple. The springs are of small dimensions only, and their weight does not have any effect in distorting the frame, nor in straining it by the action and reaction of the forces which are applied to them.

The guard plates are disposed so that the inferior row of bolts employed in fixing them to the side-pieces, and which are required to offer the greatest resistance, may embrace a great length of wood, which prevents the side pieces from splitting under the effects of a shock or any other accident.

If, therefore, we examine the entire arrangement of the frame of the carriage of the left bank, we shall see that it is excellent. This portion of the *material* of the line, moreover, has not required repairing for many years. We cannot find more than one serious defect in it, which consists in being furnished with a single buffer only, like the frames of the right bank, and of a similar character to those in use on the Newcastle and Sunderland Railway (Brandling Junction).

The frames of the carriages on the St. Stephen's (Plates 22 and 23), being formed without diagonal pieces, are liable to become distorted.

The axles of the four-wheel carriages on this railway being very close, the frame consequently gets curved, and the bodies are subject to continual motion by

balancing, which is very disagreeable to the passengers. This movement, however, doubtless does not take place in the six-wheel carriages. (We have already stated that we shall treat thoroughly hereafter, in the article on the bodies of carriages, on the respective advantages and disadvantages of carriages with four, six, and eight wheels.) The springs, being placed between two side pieces, do not appear to us well disposed. The points of support are too far from the wheels, and the greasing must also be difficult. The frame is too narrow to allow of the body, if it be of sufficient size, being firmly secured.

We must also state that we are by no means advocates of exterior wheels with the gudgeons inside. This arrangement, whatever may be said of it, appears to us very dangerous. The axle would doubtless break inside the grease box, in the event of fracture, (which would be in accordance with experiments made with the locomotives on the London and Birmingham Railway,) and the wheels would consequently remain on the rails.

But if, on the contrary, the axles should break flush with the nave, (which accident actually took place on the same line, as though to contradict the results of experience,) the wheel must become wholly detached from the carriage, and the latter be thrown immediately off the rails, or the body may fall. It is well known that the chances are greater of its breaking flush with the nave than at any other part.

The system of the grease boxes is very simple, but is intended for the service of oil instead of grease. It would be as well to make some experiments and comparisons previously to the substitution of oil, which is so generally preferred, in order to make ourselves acquainted with the expense, the friction, and the wear of the axles.

In respect to the value of traction-spiral springs, we can but feel surprised at the favourable opinion expressed upon them by the engineer of the St. Stephen's Railway, as we believe that they are generally condemned, and that the wear is very great in the wagons; perhaps fresh experiments might throw more light upon the subject.

The fastenings of the several parts do not appear to us very advantageous. The rods are badly guided, or rather, are not guided at all; the buffers are heavy, badly supported, and prevent the use of stretching pieces.

Lastly, we shall conclude our remarks on the buffing and traction apparatus of the carriages of St. Stephen's line, by saying that this apparatus savours too much of old iron, and appears to be rather the work of the smith than the engineer.

The frames of the carriages on the line from Paris to Rouen (Plate 20) are

put together better and more simple than any that we are acquainted with. The whole is very strong, and the several parts are solid and well united.

The traction and buffing springs, like those for the suspension, are of a reasonable weight, and are not liable to strain the frame in their play with the rods which transmit their action to them.

The buffer-rods are wrought in one piece with the plate carrying the wooden disc. There is no difficulty in securing them in this way, and the deficiency of strength presented by a riveted plate is thus remedied.

We have already alluded to the advantages of the curve of the suspension-springs being but slightly bent, which renders them very easy.

The grease boxes have, in our opinion, one defect—that of allowing the dust to lodge on the gudgeons of the axles, which are not protected like the carriages of other railways in the environs of Paris.

Having described the different kinds of frames which carry the bodies of the wagons forming the permanent plant, we will now direct our attention to the bodies, commenceing with ballast wagons, which we have before classed next the earth-work wagons.

The body of a ballast wagon generally consists of a simple flat body, of slight depth, and differs from that of the earth wagons merely in not being capable of being turned up and emptied from one of its ends.

As this body is loaded and emptied with shovels, it is therefore essential that it be flat and large, in order that the sand may be emptied quickly.

Ballast wagons with deep bodies have, however, been tried on the Versailles line (left bank), which were emptied by a trap-door, without stopping the train; but the sand sometimes fell upon the rails when it was discharged, and was found to present some difficulties in managing.

It does not appear that the results hitherto obtained with these wagons are sufficiently advantageous to warrant our recommending their use.

If the bodies are formed of large dimensions, they become very heavy when filled with sand, and are consequently placed on six wheels, as those on the St. Germains Railway, and on both of the Versailles lines; but on other lines, where their capacity is less, they are only supplied with four.

The earth-work wagons are sometimes employed for ballast, for the purpose of making the most of the provisional material of the railway, but they try the ways exceedingly, on account of not being suspended; and as they are in general of very rude construction, we therefore consider such economy very short-sighted. The employment of wagons with cast-iron wheels, probably partly worn out, and often of smaller diameter, is further dangerous.

DOCUMENTS, ESTIMATES OF COST, AND MINUTES OF SPECIFICATION.

EXTRACT FROM THE "REGULATIONS RELATING TO THE MAINTENANCE OF THE LINE AND POLICE" UPON THE RAILWAY FROM STRASBOURG TO BASLE.

Chapter I.—*Of the Engineer of the Railway.*

Art. 67. The Engineer is charged specially with the maintenance and preservation of the line, properly so called, of the works belonging to it, and generally, of all the buildings serving for the purposes of business connected with the railway.

Art. 68. He is, moreover, charged with the police of the road throughout the whole extent of the line, and all infringement of the police regulations established for the *surveillance* of the railway will be referred to him.

Art. 69. He is to regulate and to direct the transmission of all signals.

Art. 70. He is to secure the free passage of the trains; and no train is to be dispatched upon any parts of the line upon his intimating, at any particular moment, that the line is not passable.

Art. 71. The Engineer of the railway is to take charge of the plans of the line, and of the various works and matters connected therewith. He is the depositary of the models of the rails, chairs, wedges, pegs, crossing-points, tools, &c.

Art. 72. The Engineer must inspect, once a month, at the least, the entire line under his care. He must satisfy himself that all the regulations are observed, and that the agents and overseers acting under his orders perform their duties punctually.

Art. 73. He should visit, in turn, all the works, ascertain the quantities of materials employed, and the manner in which they have been used; he should take care that the stores of materials, tools and tackle, distributed amongst his men throughout the entire line, for the maintenance and repairs of the road, are kept in proper order.

Art. 74. He is to take notice of whatever work is urgent, or required to be executed *instanter*, and is to render an account thereof to the Board of Directors.

Art. 75. He is to make plans for the works, to submit them to the Board of Directors, and after receiving due authority, to cause them to be carried into execution.

Art. 76. Unless in cases of extreme urgency, and under the express condition of reporting immediately to the Board, he is not to give orders, nor allow any works to be executed, which have not been previously authorized by the Board.

Art. 77. The Engineer of the railway is to send in a report weekly to the Board of the state of the line, and of the police, as well as of the works in progress, and those about to be undertaken.

Art. 78. The Engineer of the railway to see that a proper stock of rails, sleepers, chairs, pegs, and wooden wedges, are given out from the stores to the workmen, so that the repairs of the road may be executed at the most suitable periods, and be kept constantly complete and in good order. Upon an article being used, it ought to be immediately replaced from the nearest storehouse. The applications for these articles at the storehouses to be made in the same manner as for any other article of consumption.

Art. 79. The value of the articles used to replenish the reserved stock must appear in the statements of expense, and be added to the price of the articles received from the warehouses, and the central storehouse.

Art. 80. The Engineer is to watch over, and hold possession of the documents relative to his duty, and he is responsible for all errors, and every irregularity which may occur.

Art. 81. He is to verify and certify the payment of accounts drawn up under his care, by the overseers, transmitting them to the Board.

Art. 82. He is to receive from the overseers the bills of any petty charges, relative to the works, which have been authorized to be executed away from the workshops.

Art. 83. He is to remit, at the end of every month, these bills to the Board, adding, as vouchers, the invoices of the parties who supplied the articles and the delivery-bills of the overseers.

Art. 84. He is also to render monthly accounts of the supply of ballast which has been sent to him, and for which he is responsible. The notes of these expenses will be his discharge.

Art. 85. The Engineer is to give an account, through his overseers, of whatever they require, and send himself to the central storehouse, or to the warehouses from which the articles demanded are to be supplied.

Art. 86. He is to see that the overseers do not receive articles without invoices, and that they punctually return the receipts for the articles received, which they ought to withdraw from their stock-book.

Finally, at the end of every month he is to transmit a note of these expenses to the Board, after he has examined it, adding thereto the list of receipts, at the bottom of which the invoices must be annexed.

Art. 87. The engineer to keep an account of the amount of work done by his men in the various works which he has ordered, and to see that the receipts proving the work done, are attached at the bottom of the invoices. At the end of each month, he is to send to the Board an account of the expenses, with the requisite vouchers.

He is also to keep invoices in the warehouses of the articles which have been worn out, and replaced by new supplies. The overseers must take care that these articles are received in the best possible order.

Art. 88. The engineer will be assisted in his duty by five overseers, one of whom will act as chief, to whom the works divided as follows will be confided:— The division from Strasbourg to Benfeld, from Benfeld to Benniwihr, to Bolliwiller, from Bolliwiller to Mulhouse and to Thann, and from Mulhouse to Basle.

Art. 89. Each overseer will have two inspectors under his orders, and for the service of the division, and as many way-keepers and workmen as the service may require.

Chapter II.—*Of the Overseers.*

Art. 90. The superintendence of the maintenance of the line and of the police, is confided to five overseers, each being entrusted with a division of the road. The overseers are moreover charged with the management of the works, which are executed in their respective division, whether new works, or repairs of buildings, works, &c.

Art. 91. The overseer must reside in the division of the service with which he is entrusted.

Art. 92. Each overseer will have one or two inspectors under his orders, to assist in seeing that the work prescribed to the road-keepers and workmen is performed with the utmost precision, so as to secure the free passage of the trains, for which he is responsible to the extent of his division.

Art. 93. The overseers are to write down every day in the note-book of every inspector, the orders regulating the work to be performed the following day. These will contain the hours for each and the direction of his beat; if it is to be performed in a single or partial journey; the workshops at which he is to work; and it fixes a spot in his subdivision where he can be found to take any verbal orders, and to receive fresh instructions. The overseer comprises the beats of his inspectors as well as his own, so that the guards and workmen are aware of the constant superintendence to which they are subjected, and therefore have no opportunity of neglecting the duties which it may be their business to perform at any time.

Art. 94. The overseer is bound to visit on foot, at least six times per month, each of his guards and workmen; he must sign their books, and see that the inspectors have made their beats at the hours prescribed; he is to observe the state of the line, visit the gates and the level crossings, look to the preservation of the slopes and cuttings, inspect the condition of the bridges and viaducts, especially of the crossings and branching-off places along the line; he is to cause all the repairs to be executed without delay, which he may deem indispensable to secure the safety of the trains; to ascertain himself whether the dressings and repairs of the way, as well as the replacing of the rails and chairs, are performed with proper accuracy and strength, and in conformity with the rules of art; he is also to take notice whether any of the parties situated on the borders of the railway make encroachments.

Art. 95. At harvest-time, or when agricultural operations, or the cutting of timber, occasions certain roads to be more frequented, which have little traffic during the rest of the year, the overseers should provide and select temporary guards from amongst the neighbouring workmen, if the ordinary ones are not sufficient to perform their duties effectually.

Art. 96. Once every month (from the 15th to the 20th) he is to inspect the tools, implements, and signals, used by the guards and workmen, to see that they are in good condition, to place upon the pay-lists, when necessary, any stoppages of the workmen's wages which may be required to replace articles lost or destroyed through their neglect.

Art. 97. To inspect in the different depôts the quantities of materials remaining in store, and see that those articles used have been properly applied.

Art. 98. The overseer ought to inspect, in his rounds, the stock of rails, sleepers, chairs, pegs, and wooden wedges delivered to each keeper; to see that they are complete, and that all articles replenished or out of use are returned to

their places. Every article constituting this stock ought to be replaced after being used.

Art. 99. Besides the assortment of tools with which each workshop is to be supplied, he is to keep a certain stock in reserve: he is to distribute these amongst the inspectors, placing them in the warehouses at the stations, in order to have them ready when wanted for additional workmen.

Art. 100. As soon as an accident is signalled to him, the overseer is to repair immediately to the spot, whether day or night, and is to lend every aid and assistance in his power, so that the free passage of the train may be secured as soon as possible.

Art. 101. Whenever any offence has been committed in his division, the overseer is to give notice immediately to the commissary or agent of police in whose district it may have taken place, and he may himself exercise the power granted him to draw up the *procès-verbal* whenever he may deem it expedient.

Art. 102. The overseer to transmit daily to the engineer a report of the progress of the trains, a note respecting any signals for lessening the speed, whether the trains pass the crossings, platforms, &c., with too great velocity, &c. Offences, accidents, the names of workmen, absences, applications for leave of absence, sickness, punishments, state of the road, rails or chairs replaced, suggestions, requisitions for tools, tackle, or materials for that part of the division which he visits.

Besides these daily reports, which merely contain an account of the events occurring on the previous day, the overseer shall transmit, as soon as possible, special reports of anything extraordinary—such as accidents, grave offences, &c., of which it may be necessary that the Board should be immediately informed.

To make a report on the Monday of every week upon the maintenance of the way, embracing the work performed in each workshop, and that which is to be performed the following week, stating any extra workmen that may be necessary on the works.

Twice a month (the 10th and 25th), to report upon the state of the works, the building at the stations, the gates, enclosures, slopes, &c.

Once a month (the 22nd), to draw up a list of all the tools, tackle, and other property of the Company in the hands of the guards and workmen, or in the warehouses, as stock, after an approved form.

Once every month (the 26th), to deliver an account specifying the coke and articles picked up on the road by each guard, and the receipt notes of the station-men to be delivered as vouchers to whom the articles were entrusted.

Art. 103. The overseer is to draw up and sign the accounts of expenses incurred in his division, and transmit them in duplicate by two different deliveries to the engineer, on the last day but one of the month.

Art. 104. The chief overseer has the inspection of the other divisions of his line besides the duties of his own division, and he is to keep the engineer informed of the general superintendence by especial reports.

Chapter III.—*Of the Inspectors.*

Art. 105. The inspectors are to be subject to the orders of the overseers charged with carrying out the whole of the regulations concerning the police, and maintenance of the ways. They ought to be selected from among the chief layers, so that they may be competent to direct the chief workshops, and work themselves whenever it may be necessary.

Art. 106. The inspectors ought to have their residenee near a station, at a spot fixed upon by the engineer. They must not quit the line at any time during the day or while the traffic lasts, in common with the workmen and guards.

Art. 107. They ought to pass, on foot, once a day at least, over the whole of their section, to inspect the way, to examine minutely the crossings and platforms, to countersign the books of the guards and the lists of attendances in the workshops, specifying the hour of their visit.

Art. 108. To attend every day at certain places on their stations, as may have been directed by the overseer on the previous day, to make their verbal report to him, and to receive orders for the following day. These orders are inserted in the Inspector's Book, and fix the hours and the direction of their beats, and the workshops where they are to stop to give orders and work. The overseers may give permission to the inspectors to ride by particular trains, and which is to be delivered each time to the guard of the train.

Art. 109. In case of accident, the inspector is to give notice to the overseer, and to proceed to the place of the casualty to lend aid and assistance. He is to direct the workmen to act in whatever manner he may deem expedient until the arrival of the overseer, when it refers to casualties connected with the road, extinguishing a fire, &c.; but if the accident is confined to the train, he is to place himself at the orders of the conductor of it.

Art. 110. Each inspector is to have a stock of tools to replace immediately any which may be destroyed or lost by the guards, or in the works; or with which to provide any additional workmen, whom he may add to the ordinary

number employed. This stock to consist of one crowbar, for dressing the rails, two rules of 4^m 60 in length, one iron distancing rule (*gauge*), six earth rammers, two augers, two graving tools, four files, one screw wrench, one large hammer for setting the rails, two screw-drivers, one anvil, six barrows, six baskets, two round rammers, three levels, one large square, two *laying* rammers, six iron pickaxes, one lever, two large pincers, two flat rammers for the slopes, two horns, six barrier rails, sixteen chairs for crossings of different sizes, two points ditto, one pair of shears to cut the hedges. And, further, a stock of thirty rails and thirty sleepers distributed near the watch-boxes.

It is his duty to see that this stock of tools is complete. Whenever he requires any articles that are lost or worn out to be replaced, he ought to report the latter, and send them afterwards to the central storehouse, observing the formalities prescribed, and he is responsible for all the property which he receives.

CHAPTER IV.—*Of the Road-guards.*

ART. 111. The duty of the road-keepers is principally to secure the free passage of the line. These guards are responsible for all stoppages, and all delays which may happen to a train in consequence of obstacles on the line.

ART. 112. In order to accomplish this, they ought to watch their beats very closely, to remove from the line anything which may have been thrown thereon; exhibit and transmit the signals; open and close the gates of the roads crossing the railways; prevent people passing or standing thereon, or upon the sides of the railway, unless they have business there or permission, or are agents of the public authorities; drive away all cattle which may stray upon the road through neglect of their drivers. The guards are bound, moreover, to execute the work which is prescribed to them for the preservation and proper maintenance of the line.

ART. 113. The guards are to be obedient to the inspector under whose orders they are immediately placed, and to the superior agents of the company; they ought, moreover, to aid and assist the guards of the trains and the agents of the public authorities, whenever required.

ART. 114. The road-guards to execute punctually, and at the prescribed moment, whatever orders may be given to them.

ART. 115. The guards to wear, when on duty, a black-glazed leather hat, with a band of copper, upon which is to be cut the word "Railway," and the number of the section assigned to them.

ART. 116. Neither rain, snow, nor any weather will be allowed to furnish an

excuse for the absence of the guards, and they are not to leave the railway at any moment during the day, under penalty of immediate dismissal.

The time of attendance on the line is fixed according to the seasons, and it is sufficiently early to allow of their carefully examining the line throughout the extent of each section before the first train passes.

They must not quit the line until after the appearance of the signal for leaving off work, as will be hereafter explained.

Art. 117. A watch-box is placed at the disposal of the guard, to receive the tools and implements entrusted to his care, and to which he may retire to take his meals. The cleanliness of the watch-box, and the good order of the articles deposited therein, will be strictly insisted on.

Art. 118. Each guard will be provided with the following articles, for which he is responsible—namely:

The plate of copper fastened to his hat, a copy of the regulations which relate to his duty, a copy of the special regulations relating to signals, the book in which is inscribed the hour of his passing by the inspector and the orders which he gives, a belt, a horn, flags and lanterns prescribed in the special regulations for signals, a tin can, a hammer for driving the wedges, an iron shovel, a pick-axe, an iron rake, an iron scraper, an iron rod, a hoe, a wooden rod, a tri-coloured flag for the flagstaff, a trowel, a steel, a paper of tinder, and another of matches, a broom, five joint chairs and ten intermediate ones, and twenty wedges, ten pegs, and twenty-four nails. All articles capable of being marked, shall have the letters S B inscribed thereon; they are to be renewed according as they are used or worn out, but the value of those lost or broken must be reimbursed by the guard.

Art. 119. At every spot where there are paths, roads, or ways crossing the line on a level with the railway, barriers or gates are to be erected on the outside of the rails and small mounds, to prevent any one passing across the line at the time that the trains are passing, and which are to be hung either on wooden or on iron hinges. These barriers are to be attended to by the guards in whose beat they may be placed. They are to be closed across the road from the time of receiving the signal until the passing of the train, but leave the road open at other times.

As the same guard may have several gates to attend to, according to the distance separating them, and the amount of traffic along the roads, he is to remain at the crossing presenting the greatest amount of traffic at the proper

moment, or whichever may be pointed out to him by the overseer of the division during the passage of the train.

ART. 120. Each guard is to keep in his watch-box a bill indicating the hours of the passing of the ordinary trains upon his station.

ART. 121. He must take a turn over his section before the communication of the signal announcing the approach of the train, in order to be sure that the passage is free, and that the grooves along the line upon the level parts are thoroughly clear. He is afterwards to place himself abreast of his watch-box, to receive and return the usual signal.

ART. 122. After having given the signal, the guard should close the gates, and stand at the post assigned to him, always on the right hand of the passing train, he must then await its passing, and stand with the right arm stretched out, parallel to the road, thereby indicating that the train may pass along in safety.

ART. 123. The guards near the stations place themselves with the arm extended perpendicular with the direction of the line, thereby indicating that the train is to stop.

ART. 124. Each guard must take care to observe whether the passing train exhibits a signal announcing that it will be followed by another, and this is necessary as he may be called upon by his superiors to prove that he has observed the signal.

ART. 125. After the passing of the train, the gates are to be opened, and the crossing of the railway permitted.

ART. 126. When a train is expected, and immediately after its passing, the guards should turn their eyes in a direction towards it, so that they may be enabled to repeat without delay any signals of assistance which may be given.

ART. 127. After the passing of the train, the guard should examine the whole length of his district, to ascertain that nothing is out of order along it, to satisfy himself that the rails are in their proper places, and to replace any wedges which may have become detached from the chairs.

ART. 128. The examination to be made by day with two flags, and at night with two lanterns, but covered with their shades.

ART. 129. If the guard should discover a broken rail, a slip of the earth, or any derangement which he cannot himself repair, and which is of a nature to endanger the train, he should instantly exhibit the signal to stop in the middle of the line, cause it to be repeated by the next guard upwards, and afterwards report it with as much dispatch as possible to the foreman of the nearest works, so that the damage may be promptly repaired.

He is also to inform the foreman of the works on the road of any derangement which he may have observed upon the road, however unimportant it may appear. If the derangement does not require the stoppage of the train, he will merely exhibit the signals of "*slower*" and "*attention*."

Art. 130. The guard must carry a hammer at the time of making his examination, to tighten the wedges; and a quantity of wedge-pins and nails to replace any which may be deficient, besides the two flags and the two lanterns.

Art. 131. The men are to be stationed between the guards at night to assist them in watching the way, in taking care of the rails, and in transmitting the signals.

Art. 132. The guards are to pick up all the coke which may fall on the ground along their beats, collecting it carefully once a day, in a sack kept for that purpose. When the sack is full, they are to carry it to the nearest station, and deliver it to the station-master, taking his receipt for the same.

Art. 133. Any luggage belonging to passengers, packages, &c. which may happen to fall from the carriages and wagons during the progress of the trains; also all bolts, screws, and any articles belonging to the Company, which may get detached from their places, must be scrupulously collected by the guards, and handed over to the station-master, or to the nearest warehouse of the neighbouring station, always taking a receipt for them. A ticket should be tied to the article picked up, indicating the date, and place where it was found.

Art. 134. The necessary signals to be made every evening from the different points for leaving work, in order to apprise the guards, workmen, and clerks at the stations, that the trains have arrived, and that they may therefore leave. This signal is to be given by two blasts of a horn, and by passing the white light twice across the line, previous to suspending it before the watch-box. It must be answered immediately by the next guard. Whenever this is omitted, the guard who has not had his signal answered should walk towards the next post, until he observes the signal repeated. With regard to the workmen stationed between the guards, those who have not horns are to call out, "Leave work."

Chapter V.—*Of the Workmen.*

Art. 135. The line is divided into districts of 4 kilometres (4360 yards) in length, for the purpose of keeping it in order—each district being maintained by a body of workmen, the number of which varies, and who act under the superintendence of a foreman.

Art. 136. Each workshop is to be provided with the following tools, for which the foreman is responsible:—One order book, one case for the flags, two flag signals, one horn, two driving hammers, one plumb level, two pairs of large pincers, one smaller pincers, one level shod with iron, three round rammers, two laying rammers, three pickaxes. Moreover, every workman should have a shovel belonging to him. The shops which have crossing-places in their district should have one small hammer, and two drivers for the wedges of the points.

Art. 137. The workmen are to be constantly on the line from the hour of their arrival, which is to be determined by the overseer, until the signal for leaving work.

Art. 138. The foreman and his assistants are to make a strict examination of the whole district every Sunday morning, rail by rail; they are to connect the joints and to place wedges between the chairs and the rail, if necessary. The foreman is to take a note in a book of the places along the line requiring repair, the nature of these repairs, and he is to determine what portion of the work shall be performed on the several days of the following week. He is to submit this note-book to the overseer, and obtain his approval to engage additional men, if the regular workmen are unequal to the emergency.

Art. 139. One half of the men will have a holiday on Sunday afternoon, while the other half remain on the line to keep guard and superintend the barriers.

Art. 140. Sunday is to be devoted to the examination of the line, and the workmen are to work on the other days of the week. The duty of inspection devolves upon the guards, and the workmen are not to walk along the road under pretence of inspecting it.

Art. 141. Whenever a guard makes known to the foreman any defect which he has detected on the line, the latter ought to proceed to the spot immediately, and decide, upon his own responsibility, whether the repairs should be deferred or performed at once.

Art. 142. In the case of a broken rail, the workmen should instantly slip the nearest sleeper under the broken part, by which it may be rested upon the

middle of a chair, and give the signal for slackening speed immediately. The foreman should then consider the best mode of replacing the broken rail. In case of none other being handy, he should add a sixth sleeper to the five which originally supported the broken rail.

No. 143. When a foreman requires to change a rail, he should select such a time in the day when the spot is free of traffic, and he must take care to plant signals for stopping in the middle of the line on each side, and at a distance of 400 metres (436 yards) from the place disturbed, in order to stop any engine which by chance may be passing.

Art. 144. The workmen are to be constantly informed of the hours when the trains pass, and they ought to be perfectly acquainted with the system of signals, in order not to stop or impede the progress of ordinary or extraordinary trains by executing the same badly.

Art. 145. Whenever the workmen discover any dangerous or impassable place on the line, they should plant the signal for slackening speed or stopping, as the case may require, unless the guard has already done so.

Art. 146. Upon the approach of a train being signalled, they should remove all their tools and implements to the distance of at least a yard, place themselves on the *banquette*, or bank next the line they are repairing, and in sufficient time that the driver need not slacken his speed.

Art. 147. In case of signals of distress, the foreman, who is to be provided with a horn and flags like the guards, should transmit this signal by blowing his horn, and unfurling his flag, and by running to the next post, until the signal is returned.

Art. 148. When work is over for the day, the workmen are to remain stationed between the guards at the different barriers, in order to aid the police, and transmit the signals along the line, and they are not to quit their posts until they have received and transmitted the signal for leaving work.

Art. 149. The workmen are to be employed on other work besides the maintenance of the way with which they are specially charged, as the repairs of hedges, inclosures, the crossings, &c. At the time when snow lies on the ground, they are all to be provided with brooms, and kept constantly clearing the line.

Art. 150. The workmen are to hold themselves ready to act on all emergencies, day and night, wherever they may be. They are to give every assistance to the police and guards of the trains, in case of need. They are to supply the places of any absent guards, under orders from the overseer or inspector. They are also, under some circumstances, to perform the duties of temporary gate-

keepers for particular roads, and at certain hours, according to the orders of the overseer.

ART. 151. The foreman is to be responsible for any mistakes committed in his workshop.

ART. 152. The foreman is to carry a time-list, upon which the names of the men at work are to be inserted, and which is to be checked daily by the inspector.

*Minutes of Specification for the supplying of Frames and Bodies of the First and Second Class Carriages on the Orleans Railway.**

This contract comprises eight first-class carriages, one complete carriage of the second class, and twenty-four bodies of carriages also of this same class.

The company to have the power, within a fortnight after signing the contract, of extending the number of first-class carriages to ten, if they are desirous of it.

The carriage bodies of each class to be constructed of ash, with panels of plate iron, like those now standing at the shops of the company in Rue du Chevalleret, and the form, dimensions, trimmings, and arrangement to be exactly similar.

The frames of carriages of the first class to be also of ash, and in every respect similar to those standing in the shops of the company, and, like them, furnished with complete buffing and drawing apparatus, safety chains, with the proper irons of attachment.

The whole of the timber used in building the various parts, to be dry, sound, and square, without splits, bad knots, or rings, and free from rottenness, and neither weak, nor heated, nor cut in the direction of the grain.

All the joinings to be made with the greatest care.

All the furniture and fittings to be of the first quality, and moreover, in conformity with the samples.

The bodies shall not be painted until after they have been examined and received *in the rough* by the engineer who has charge of the stock.

* The frame of this carriage is nearly similar to the "*Carriage de luxe*," Plate 12; and the bodies of the first-class carriages like those of the other carriage on the same plate. The bodies of the wagons are like the wagons employed on the same line, but composed of three departmentsonly. (The roof is not furnished with seats.)

	frs.	£.	s.	d.	frs.	£
The following sum shall be paid for the first-class carriages, upon their being perfectly finished, as before described, including the frame . . . . each					6000 =	(240)
Viz.—For an ash body with panels formed of plate-iron, and consisting of three compartments, forming a *berline* with eight places, glazed sashes, and the roof covered with zinc	850 =	(34	0	0)		
To binding the bodies with irons at the corners, inside, to render them strong; to eight irons formed like a T square, with rings, fixed to the body for the purpose of placing it on the frame of the carriage and lifting it off as required, eight screw boxes furnished with *flies'-wings* and eight *Roman* screws, sixteen bolts to fix the aforesaid iron-work.						
The doors to close with laps and patent joints and handles, with patent springs, two lamps to be placed on the roof to light the three compartments.						
Eighteen glass sashes; the springs to be all trimmed and in their places, and the lining of the body ornamented with polished heading	530 =	(21	4	0)		
The inside of the bodies to be lined with blue cloth, with red and blue binding, the side cushions of red leather, two stalls in each body, the stuffing to be horse-hair and hemp of good quality, in the proportion of 90 livres of horsehair to 150 of hemp.						
The body to be painted brown, polished, picked out, and varnished	1348 =	(53	18	0)		
	2728					
Extras 10 per cent.	272					
Total cost of the body of 1st class carriage.	3000 =	(120	0	0)		

	frs.	£ s. d.	frs.	£.
Brought forward			3000	=(120)
Each *double frame* is composed of two frames, two sets of diagonal pieces, two cross pieces, and three of brackets.				
Four round pieces of turned elm adjusted and fixed, twenty-four strong iron squares fixed to the frame with bolts	400	= (16 0 0)		
All the necessary buffing and drawing apparatus to be accurately fitted, finished and fixed in their places; four point-irons, or holdfasts, and springs, six foot-steps of two sizes, each fixed with bolts; eight double straps to fix the suspension springs; fixing guard-plates with sixteen strong bolts.				
Finally, fitting and fixing all the iron-work necessary for the due strength and completion of the carriage, two buffer-springs, and four suspension-springs, painting, double frame, iron rings, wheels, and axles . . .	2328	= (93 2 6)		
	2728			
Extras 10 per cent.	272			
	3000			
Total expense of frame of carriage			3000	=(120)
Total, for a first-class carriage . . .			6000	=(240)

The iron work for fixing the bodies upon the frames must be fitted with such exactness that each body may be placed, if required, upon any of the frames.

The guard-plates must be fixed in such a manner that the axles shall be parallel between them, and perpendicular to the longitudinal axis of the carriage.

	fr.	£
The following sum shall be paid for each body of the second class:	2000 =	(80)

	fr.	£ s. d.
Viz.—To an ash-wood body, with panels formed of plate-iron in three compartments, for 10 places, with running sashes, and the roof covered with zinc	820 =	(32 16 0)
The interior of the three bodies to be of iron, with 40 squares, fixed with screws and bolts; 8 irons, forming a T square, with rings fixed to the body for the purpose of placing it on the frame of the carriage, and lifting it off, as required; fixed with 16 bolts, 8 screw-boxes furnished with *flies'-wings* and 8 *Roman* screws. The 6 doors to be iron-bound, copper-lapped, with 6 handles, and patent catches.		
To lamps to light the three bodies; 18 pairs of glasses for the sash-frames	350 =	(14 0 0)
The inside of the bodies to be lined with stuff, 6 stuff cushions, padded with horse-hair and hemp, the latter in the proportion of two-thirds only; 18 sash-pulls, 6 door-straps; painting the carriage, according to pattern	649 =	(26 0 0)
	1819	
Extra, 10 per cent.	181	
Total for the body of a second-class carriage . .	2000 =	(80 0 0)

For a second-class carriage, delivered complete, and made precisely similar to the carriages of the first-class, according to the specification of these carriages, the sum of 3000 fr. (£120) shall be paid, the total amounting to 5000 fr. (£200). The company is to be at liberty to make such alterations during the progress of building as may be deemed necessary, provided always that such alterations do not render the expense greater to the contractor.

The aforesaid carriages of first and second class, and bodies of the second class, to be delivered completely finished, and ready in the manufactory of the company, by the 31st March, 1840, at the latest. And if, through any fault of the contractor, the whole of the carriages and bodies included in the present con-

tract are not delivered at the appointed period, they shall be returned, and deducted from the amount of his account, and damages allowed for every week's delay, as follows:—viz.

	Francs.
For each complete first-class carriage	100
For each complete second-class carriage . . .	50

which is to be without prejudice for any further indemnity for losses which the company may sustain.

The payments shall be made in the following manner:—One-third to be paid when the contract is signed; one-third after the receipt of the bodies of the carriages *in the rough*, accordingly as they progress; and the last payments after their delivery, and upon their final reception at the works of the company.

The two complete carriages of the first and second class built according to the agreement of the 12th April last, shall be taken, and the alteration and improvements which have been made during the building to be allowed to the contractor, and they shall be included in the number of carriages forming the present contract.

And, further, seeing that the said carriages, which were executed as patterns, have been already delivered into the shops of the company and accepted, they are to be paid for immediately after signing the present contract, viz.:—

1st. A sum of 11,000 francs for the first-class carriage complete, and for the second class already delivered, (440*l.*)

2ndly. A sum of 30,000 francs (1200*l.*) being a third of the total value of the bodies and carriages supplied.

Any dispute which may arise between the company and the contractor respecting the conditions of the present contract and specifications, shall be decided by three umpires, upon the choice of which the parties shall agree within one week. In default of which, the umpires shall be appointed by the Tribunal of Commerce of the department of the Seine, at the request of either parties applying.

The arbitration shall decide in a friendly manner, and its decision to be final, without any reference to legal forms or delays; and it shall not be able to set it aside by appealing against it, or by any civil or legal process whatever. The cost of arbitration shall be regulated by the umpires.

The registering of these presents to be at the expense of the parties interested.

Drawn up and delivered by the undersigned engineers.

Minutes of Specification for the construction of English Carriages, including the wheels and axles.

Each carriage to consist of three compartments, each being 4 feet 11 inches long, making a total length of 15 feet 6 inches. Their height, from the floor to the roof, to be 4 feet 6½ inches, and width 6 feet in the clear, exclusive of furniture.

The woodwork of each compartment to be of the best ash, and of the following dimensions—viz., the sides of the floor to be 2½ inches by 4½ inches, the upright posts at each corner, and at the doors (making twenty in number in the three compartments) 2½ inches. Those at the doors to be strengthened in the interior by vertical pieces of birch-wood firmly fixed to the seats. The top rails to be 2½ inches by 1½ inch, and there must not be less than 12 at each extremity. The cross piece of each partition of the interior to be 2½ inches by 1 inch. The seat-rails (making ten in number in the three compartments) 1½ by 2½ inches. The circular pieces supporting the roof (making three for the middle compartment and four for the two others) 2¼ inches wide and 1⅝ inch thick. The sides to be formed of panels of the same thickness as those at the ends of the carriage, and to be similar in every other respect. The floor to be constructed of 1¼ inch American pine planking, bound beneath by three bands of wrought iron, 1½ inch broad by a ¼ of an inch in thickness, passing from one end to the other, and fastened by 100 bolts and screws.

The internal partitions, seats, and planking of the roof, to consist of American pine, ¾ of an inch thick. The roof to be covered by three pieces of leather, weighing at least 38lb each, protected on the top by oak ribs 2¼ inches wide by ⅝ of an inch thick, placed at distances of 3 inches from each other, and fastened by screws. An oak cornice to be formed all round, 1½ inch square, screwed and projecting sufficient to keep off rain from the panels of the carriage. This cornice also requires to be channelled, and raised rather higher on the outside than the top of the carriage, and to be painted white.

Seats for the acommodation of two persons are to be constructed at each end of the roof, and to be furnished with iron hand-rails, and three footsteps covered with leather, &c. The support for passengers' feet consists of a plank of birch wood, sustained by iron brackets.

The roof to be furnished with iron rods, for a space of 8 feet 6 inches, placed lengthways and across to hold the luggage; these irons to be ⅝ of an inch in diameter, and to be supported at equal distances by uprights 4½ inches high, the whole to be covered with a waterproof cloth fastened by straps.

The outside of the carriage to be formed entirely of wood panels thoroughly dried, the highest of these to be $\frac{1}{2}$ an inch in thickness, and the bottom panels 5-16th of an inch, and those of the ends $\frac{1}{2}$ an inch; these panels to be fitted with canvas in the first place, fastened by means of copper pins at distances of 1 inch from each other, with another canvas fitted on afterwards. The mouldings to be of brass, as well as the handles of the doors. Four iron lamps are requisite for each carriage, two at each extremity.

The windows to consist of good glass, 22½ inches high by 19 inches wide, and at least 5-10ths of an inch thick. The sashes to be made of oak thoroughly dried, to be 1½ inch wide, and covered with black velvet, or painted, rubbed, and varnished. Small bands of leather must be carefully placed at the bottom of the grooves which receive the glass, for the purpose of deadening the shocks. Venetians (*jalousies*) are to be added, if desired.

The painting to consist of three coats of white lead and four coats of priming, when the body of the carriage has been well rubbed; three other similar coats to be added to the preceding, and lastly, two coats of a colour to be chosen by the directors. The upper panels to be painted black, in the same way, and four coats of the best varnish to be spread over the whole carriage after the panels have received the inscription in golden letters and the ornaments with which they may be decorated.

The inside of the carriage must be entirely fitted up with cloth, the quality chosen costing, at the present time (1839), 12s. 6d. a yard of the breadth of 60 inches. The quantity required for the three compartments to be about 38 yards, and 7 dozen pieces of galoon, at 18s. the dozen, will be required for the whole. The cost of sewing to amount to 3s. 6d. a dozen, and the same price for the fitting, the handles and window-cords to be compactly covered with leather.

A good Brussels carpet to be laid on the floor, the cushions of the back and elbows to be stuffed with hair of the best quality, of which about 112 lbs. to be used in the three compartments. The seats are to be separated in each compartment by four mahogany elbows, adjusted by iron-work, fixed by screws, and furnished. Each seat to bear a gilt number on a lacquered ticket.

The body of the carriage to be secured to the frame by means of strong screw-bolts. Every part will be required to be perfectly strong, and all the iron-work of the first quality. The weight of the iron-work—viz., the rods to secure the luggage, the foot-boards, supports, &c., to be about 164 lbs.; and screws are to be used everywhere instead of nails.

The total length of the frame to be 15 feet 8 inches. The buffers at each

end to draw out upwards of 1 foot 9 inches, and the whole to be constructed of good ash, and of the following dimensions:

The side-pieces to be double on each side, to be made of two pieces brought together in the middle, and bolted, if considered necessary. They are to be 3 inches square, and united vertically by stays and iron plates; there are to be 8 of the former in each carriage, weighing 81 lbs., and 4 of the latter, weighing 74 lbs.

The extremities of the frame to be formed of two cross pieces of ash, 6 feet 1 inch long, $3\frac{1}{2}$ inches by 3 inches square, and $11\frac{1}{2}$ inches wide, at their greatest depth. These pieces to be joined in the same way as the side-pieces, but with this difference, three blocks of ash wood to be substituted instead of the iron.

The whole to be secured by 4 pieces, placed diagonally; and also by 2 longitudinal and 2 transversal pieces of ash, 3 inches by $2\frac{1}{2}$ inches, resting on the lower side-pieces of the frame, and joined by mortices and tenons into a piece of very strong ash wood, forming the middle of the contrivance. This piece is to be 2 feet 3 inches long, 1 foot 4 inches wide, and 3 inches thick. All the joints to be secured by bands and squares of wrought iron, 3-8ths of an inch thick by $2\frac{1}{2}$ inches wide, fixed by half-inch bolts. The two cross and longitudinal pieces, also those forming the lower side portions of the frame, to be furnished on one side entirely with plates of wrought iron, 3-8ths of an inch thick by $2\frac{3}{4}$ inches wide, bolted in the same manner as the iron-work previously described. The weight of this fitting to be about 244 lbs., that of the bolts and their screws to the number of nearly 350, to amount to 168 lbs.

The axle-guards to consist of wrought iron, from $\frac{3}{4}$ to 5-8ths of an inch thick, and to be firmly fixed to the side pieces of the frame, by bolts and screws. To be situated at equal distances of 8 feet 6 inches from centre to centre.

The footsteps, to the number of 18, weighing together 190 lbs., to be 12 inches by 9 inches, and fastened to the frame in the same manner. There are to be 8 roller-boxes, weighing, with the rollers, $\frac{3}{4}$ of a cwt. These boxes to be screwed under the side-pieces of the frame.

Four wrought iron buffer-rods, of the weight of 258 lbs, are to be fitted to each frame, and terminated by ash buffers 14 inches in diameter, covered with thick leather, and stuffed with hair. These buffer-rods are to rest on two large springs, each being formed of 15 steel plates, $\frac{1}{4}$ of an inch thick by 3 inches wide, and 5 feet 9 inches long, when in their places. Two other drawing springs are to be appended, formed of 6 steel plates, of the same thickness and width as the preceding, and having a length of 3 feet.

The four springs to weigh together about 361 lbs. To fit into a groove,

firmly bolted on the middle ash piece before described, and 2½ inches to be allowed for play.

The position of the buffers and the drawing apparatus is shown in Plate 16.

There is other iron work connected with the buffers and drawing apparatus, besides the buffer rods already mentioned, consisting of the rods and plates which are connected with the two small springs, and which weigh about 106 lbs.

Four square socket rings, with as many lateral plates and others as amounts together to 56 lbs; lastly, of various inferior pieces, employed in the construction of the frame work, the amount of which may make a total of 84 lbs.

The whole of the steel employed in forming the different springs to be well tempered and of superior quality. The iron rods, also, to be of the first quality—wrought, finished, and adjusted with care.

The framing to be strongly constructed, according to the best system at present employed for railway carriages. To be painted five coats of a colour harmonizing with that of the body of the carriage, and two coats of good varnish.

Three chains, eighteen inches long, to be hung at each extremity of the frame, with rings at one of their extremities, and bolts, nuts, and a strong hook at the other. The middle chain to be rather stronger than the others, as it may sometimes be used for drawing; the latter to be added merely for the sake of safety. The six chains to weigh together about 168 lbs. Coupling irons are, nevertheless, preferable to chains, and ought always to be substituted for them.

As it is unnecessary for each carriage to be furnished with a break, these will be let separately. The break apparatus consists of a certain number of levers, cog-wheels, pinions, &c., and cannot be properly understood without an inspection; the whole weight of the apparatus is about 4 cwt.

The rims of the wheels, together with the spokes, to be of wrought iron, and the nave of cast iron. The outer tire to be fastened on the inner by at least eight screw bolts, and as many nuts. The axles to be of the best wrought iron, and formed half an inch larger at the parts fitting into the naves of the wheels, which are to be securely fixed to the axles, by 5-8ths keys—the whole to be painted and varnished.

The four wheels with their axles to weigh about 18 cwt.

The boxes of the axles to be of cast iron, the four lateral springs being fixed upon them, each spring consists of twelve steel plates, ¼ inch thick, 3 inches broad, and 5 feet long. These four springs to weigh about 378 lbs., which makes the total weight of iron employed in each frame about 47 cwt.

BELGIAN RAILWAY CARRIAGES.

Details of the Cost of Carriages for the Conveyance of Passengers and Goods. 1841.

Passenger Carriages.

	frs.	
Body of carriage	1700	
Wrought iron wheels, guard-plates and grease-boxes	1300	
Buffers with springs	354	
Springs of the body of carriage	325	
Wheel covers, with the bolts connected therewith	60	
Copper ramps	40	
Rollers of doors and windows	16	
Windows	25	
Cloth	300	
Galoon	215	
Linen cloth	113	
Merino	30	
Curly horsehair	183	
The various appendages for greasing	57	
Painting, workmanship, colours, &c.	175	
Furnishing and workmanship	100	
Mounting and ditto	120	£ s.
Total	4913	= (196 10)

Carriages with Seats and Windows.

Body	1000	
Wheelwork, guard-plates, grease-boxes, springs, break	1930	
Wheel covers, supports of the seats and bolts	72	
Rods of the imperial and small pieces of iron-work	120	
Linen cloth for the imperial, and hair-cloth for the seats	102	
Blue and white ticking for curtains	20	
Curly horsehair for the seats	80	
Fitting up and workmanship, furnishing, painting, &c.	195	
Mounting and workmanship	120	£ s.
Total	3648	= (145 18)

Goods Wagons.

	frs.
Carpentry	230
Four springs belonging to the frame and one of the buffers	410
Buffers with attaching chains, drawing apparatus, straps and bolts	250
Break complete, and irons for footsteps	160
Copper bearings	40
Hooks, covering plate, straps, cross-pieces, &c.	100
Wrought iron wheel-work, guard plates, and grease boxes	1200
Workmanship of mounting	160
Total, francs	2550 = (£102 0)

Recapitulation.

	frs.	£	s.
Price of a carriage	4913 =	(196	10)
Ditto, with seats and windows	3648 =	(145	18)
Ditto, goods wagon	2550 =	(102	0)

Cost of other Carriages in 1839.

Carriage	3600 =	(144	0)
Ditto, with seats and windows	3900 =	(156	0)
Ditto, with curtains only	3600 =	(144	0)
Covered wagon	3200 =	(128	0)
Uncovered ditto	2800 =	(112	0)
A break fitted up in the interior	180 =	(7	10)
Ditto, with a seat upon the imperial	300 =	(12	0)
Timber wagon	2750 =	(110	0)
Ditto, for goods	2500 =	(100	0)
Ditto, for luggage, with sliding doors	3750 =	(150	0)
Ditto, enclosed	3100 =	(124	0)
Ditto, for horses	3500 =	(140	0)
Ditto, for cattle	3000 =	(120	0)
Ditto, for iron	3800 =	(152	0)
Ditto, for coke	2900 =	(116	0)

Bodies of Passenger Carriages, Luggage, and Horse Wagons.

	frs.
Wheels, guard plates, and grease boxes	1300
Springs of body	235
Buffers with springs	260
Total, francs	1895 = (£75 16)

Bodies of Wagons for Wood, Coal, Iron, Cattle, and Coke.

Wheels, guard plates, and grease boxes	1300
Springs of body	325
Fixed buffers	100
Total, francs	1725 = (£69 0)

N.B.—The difference in the prices of carriages in 1839 and 1841 arose from the following causes. With carriages—1stly, From the prices of wheels and springs having risen. The wheels, which were formerly made of cast iron, are constructed entirely of wrought iron at the present time, and the whole of the dimensions, both of the springs and wheels, are increased.

2ndly. From numerous modifications, too difficult to describe.

3rdly. From different appendages having been made—such as spring-barrel blinds, &c.

	frs.	£	s.	d.
Thus, the mechanism of eight blinds costs	48 =	(1	19	0)
Silk for ditto	40 =	(1	12	0)
Cords and galoon, ditto	12 =	(0	10	0)
The quantity of curly horse-hair has been increased to 120 kilogrammes (264 lbs.), at 4 francs 15 cents per kilog. (1*s.* 8¾*d.* per lb.)	498 =	(19	18	0)
The following have also been added:—				
Aloes' mats	14 =	(0	11	2¼)
Carpets	30 =	(1	4	0)
Lamps	44 =	(1	15	0)

The price of *carriages with seats only* has been diminished since the workmanship of the wheels, which was expensive, has been reduced.

Estimate for the Construction of an ordinary Wagon with seats and roof, for the Company of the Versailles Railway (left bank). See PLATE 12.

DESCRIPTION OF OBJECTS.	Numbers.	Décistères.	Kilogrammes.	Cost price.		Value.	
FRAME.				frs.		frs.	
Traction rods, complete	1	...	151·	2	90	437	90
Plate iron shields for the traction rods	14	...	30·	1	80	54	
Cast iron pieces for the drawing springs	4	...	15·20		85	12	90
Springs ditto	2	...	79·500	2	20	174	90
Ditto of the body	4	...	221·	2	20	486	20
Cast iron holdfasts for ditto	8	...	38·	2	60	98	80
Point irons	8	...	9·	2	10	22	50
Straps for springs with 3 rods	8	...	11·	2	50	27	50
Double tie rods	4	...	3·750	3		11	25
Squares to side pieces	6	...	18·	2		36	
Collars to ditto	4	...	4·500	1	80	8	10
Thin iron plates for ends of side pieces	4	...	1·700	1	40	2	40
Holding bolts for guard plates	24	...	8·500	1	60	13	60
Ditto, ditto	12	...	3·	1	60	4	80
Bolts of 32 centimetres (12¾in. long) square heads	32	...	15·	1	60	24	
Ditto 15 and 25 ditto (6 and 10in. long) countersunk heads	20	...	8·	1	50	12	
Ditto 13 and 25 ditto (5 and 10in. long) ordinary heads	70	...	13·	1	50	19	50
Washers for bolts	120	...	...	4		4	80
Countersunk screws 22/26	16	...	...	2			50
Screw with square head	8	...	...	24		1	90
Wood for frame	...	7·47	...	25		186	75
Ditto for buffers	2	·12	...	25		3	
Strong black leather for the two buffers	...	...	1·850	2	70	5	
Round-headed nails for ditto	...	...	·500	1	60		80
Raw hemp for ditto	...	...	2·		20		40
Workmanship of wheelwrights in making 17 2/3, adjusting the iron work 3/3	21	...	...	3	75	78	75
Workmanship of the mechanics	6	...	...	3	75	22	50
BODY.							
Pieces of ash for joiners' work	...	10·98	...	25		274	50
Ordinary seats	...	1·93	...	25		48	25
Beech timber for frame	...	·46	...	11		5	25
Elm planks and panels	...	14·75	...	3	50	51	60
Grisard ditto	...	21·36	...	2	60	55	55
Deal ditto	...	·54	...	2		101	10
Elm panels for lining	...	5·17	...	2		10	33
Planks for seats	...	3·66	...	3	50	12	80
Grisard ditto	...	4·24	...	2	60	10	
Deal ditto	...	2·10	...	2		4	20
Walnut panel work	24	...	...	1	25	30	
Ditto panels	4	...	...	8		32	
Sheets of paper and glass	5	...	...		05		25
Plate iron	...	...	106.		62	65	70
Zinc	...	...	85·		75	63	75
Nails	...	...	13·	1	60	20	80
Carried forward	...	...	...	...		2536	85

ESTIMATE—*continued.*

DESCRIPTION OF OBJECTS.	Numbers.	Décistères.	Kilogrammes.	Cost price.	Value.
				frs.	frs.
Brought forward	...	...	...	...	2536 85
Various screws for the joiners	164	...	...	2 50	4 10
Brass covering	...	...	6·200	6	37 20
Door hinges	24	...	...	1	24
Countersunk screws for hinges and handles	386	...	...	1	0/0 3 85
Brass door handles with springs	8	...	...	6	0/0 48
Latches	8	...	...	1 50	12
Mounting steps	4	...	5·400	3 50	18 90
Handles of the imperial	4	...	1·650	2 80	4 60
Stays, with dowels and pins	4	...	7·200	2 40	17 30
Rods and iron work upon roof	4	...	17·820	1 33	24 05
Squares and dowels for ditto	4	...	5·500	2 40	13 20
Mitre ditto	4	...	1·400	1 80	2 50
Sundry bolts for roof, steps, and dowels of lamp	32	...	3·175	1 50	4 75
Dowels of lamp	4	...	6·300	2 40	15 60
Lamp for the interior	2	...	...	16 15	32 50
Footsteps	8	...	54·	2	108
Footboard	16	...	...	75	12
Bolts of 4 & 13 centimetres ($1\frac{1}{2}$ and 5in. long)	62	...	5·400	1 50	8 10
Screws with square heads	8	...	...	24	1 90
Ditto, countersunk, for fixing the roof	80	...	...	3 50	0/0 2 80
Fixing the zinc	...	...	...	...	18
Workmanship of joiners	...	...	...	...	643
Ditto of ironmongers' work of doors	...	...	...	...	40
Ditto of Ironwork 15.	...	...	...	...	31
Plating the panels	...	...	...	...	40
INSIDE.		Metres.			
Ticking	...	52·85	...	1 60	84 53
Black trellis	...	11·30	...	1 40	15 80
Broad galloon	...	29·	...	50	14 50
Ditto, for covering the seams	...	159·15	...	21	33 40
Tacks	112	...	...	1 80	0/0 2
Raw hemp (of 78 kilogs. to the 1.)	...	...	15·600	20	0/0 3 10
Ditto	...	...	147·400	50	73 70
Packthread for galloon	...	...	·500	1 85	90
Double thread	...	...	·200	7 50	1 50
Crested nails (of 2 kilogs. to the C°.)	...	...	·400	3 20	1 30
Nails for seats and other parts	...	...	2·	1 80	3 60
Ditto for galloon	...	...	2·	2	4
Panes of glass	10	...	...	1 45	14 50
Copper frame plates	40	...	...	30	12
Countersunk screws	160	...	...	85	0/0 1 05
Soft yellow leather for rods and frames	2/10	...	...	27	5 40
Workmanship of coachmaker	...	...	...	...	70
Ditto of glazier	...	...	...	...	5
Painting	...	...	...	...	300
Conveyance to the line	...	...	...	...	8
					4357 90
Sundry expenses, use of tools, &c., 20 per cent.					871 60
Cost of a wagon, exclusive of wheels, axles, grease-boxes and guard plates					5229 50
					= (£209 3*s.* 7*d.*)

Estimate for the Construction of a Berlin for the Company of the Versailles Railway (left bank). See PLATE 12.

DESCRIPTION OF OBJECTS.	Numbers.	Décistères.	Kilogrammes.	Cost Price.	Value.
FRAME.				frs.	frs.
Traction rods	1	...	144·	2 90	417 60
Plate-iron shields for drawing . . .	14	...	30·	1 80	54
Cast-iron pieces for the drawing springs .	4	...	15.200	85	12 90
Drawing springs	2	...	78·	2 20	171 60
Springs of the body	4	...	198·	2 20	435 60
Cast-iron holdfasts for ditto	8	...	37·	2 60	96 20
Point irons	8	...	9·	2 50	22 50
Straps for springs, with 3 rods . . .	8	...	11·	2 50	27 50
Double-tie rods	4	...	3·750	3	11 25
Squares to side-pieces	6	...	18·	2	36
Thin iron plates	4	...	1·700	1 40	2 40
Holding-bolts for guard-plates . . .	24	...	8·500	1 60	13 60
Ditto	12	...	3·	1 60	4 80
Bolts, 32 centimetres (12¾ inches long), square heads	32	...	15·	1 60	24
Ditto, 15 and 25 ditto (6 and 10 ditto) countersunk ditto	20	...	8·	1 50	12
Ditto, 11 and 25 ditto (4 and 10 ditto) ordinary ditto	70	...	13·	1 50	19 50
Washers	120	...	...	4	0/0 4 80
Countersunk screws, 22/26	16	...	...	2	50
Screws with square heads	8	...	...	24	1 90
Wood for frame and buffers	...	7·59	...	25	0/0 189 75
Strong black leather for ditto	...	...	1·850	2 70	5
Round-headed nails	...	...	·500	1 60	80
Raw hemp	...	...	2·	20	40
Workmanship of wheelwrights in making the frames	17⅔				
Ditto, adjusting the iron work	3⅓	...	...	3 75	78 75
Fixing iron work	6	...	...	3 75	22 50
BODY.					
Pieces of ash for joiners' work	...	9·42	...	25	235 73
Beech timber for frame	...	4·50	...	11	49 50
Elm-plank panels	...	14·97	...	3 50	52 40
Grisard ditto	...	28·39	...	2 60	73 80
Deal ditto	...	33·63	...	2	67 25
Walnut panels	5	...	...	8	40
Sheets of paper and glass	5	...	...	5	25
Plate iron	...	...	92·	62	57 5
Zinc	...	...	69·	75	51 75
Nails	...	...	12·	1 60	19 20
Sundry screws	186	...	...	2 50	4 65
Brass covering	...	...	4·850	6	29 10
Door hinges	18	...	...	1	18
Counter-sunk screws for hinges . . . Coverings and handles	288	...	...	1	2 90
Carried forward	...	...	...	...	2287 93

ESTIMATE—*continued.*

DESCRIPTION OF OBJECTS.	Numbers.	Décistères.	Kilogrammes.	Cost Price.	Value.
				frs.	frs.
Brought forward	...	...	...	...	2287 93
Chased door-handles, with springs, &c. . .	6	...	...	7 50	45
Latches	6	...	...	1 50	9
Dowels of lamps	4	...	6 500	2 40	15 60
Bolts of 4 and 13 centimetres (1½ and 5 inches long) for footsteps	44	...	3·250	1 50	0/0 4 85
Screws, with square heads	14	...	...	24	0/0 3 55
Footsteps	6	...	35·	2	0/0 70
Footboard	12	...	...	75	9
Washers	12	...	...	4	0/0 50
Lamps for the interior	2	...	...	16 15	32 30
Fixing zinc upon the imperial	...	...	...	12	12
Plating the panels with iron	...	...	...	...	40
Workmanship of joiners	...	...	...	...	564
Ditto, ironmongers' work of doors	...	...	...	...	30
Ditto, ironwork	...	...	...	...	12 50
INSIDE.		Metres.			
Maroon cloth	...	40·97	...	12 50	512 10
Ditto serge	...	16·10	...	3	48 30
Linen for covering the mattresses . .	...	28·50	...	75	21 35
Stout grey linen	...	22·	...	1 50	33
Pasteboard	...	5·45	...	1 20	6 55
Black trellis	...	13·90	...	1 40	19 45
Broad galoon, maroon and red	...	65·35	...	95	62 10
Narrow ditto, ditto	...	207·65	...	29	60 20
Tacks	1033	...	...	5	51 63
Tassels of frame	18	...	...	90	16 20
Cords of frame	18	...	...	2 50	45
Black thread	...	...	·300	9	2 70
Galoon packthread	...	...	1·625	1 85	3
Nails for seats and other parts	...	...	1·500	1 80	2 70
Black varnished nails	...	...	·300	3 60	1 80
Galoon nails	...	...	1·500	2	3
Panes of glass	18	...	...	1 45	26 10
Putty	...	...	1·500	60	90
Copperplate frames	18	...	...	30	5 40
Countersunk screws	72	...	...	85	0/0 50
Soft yellow leather, for rods of doors . .	$\frac{1}{10}$	...	...	27	2 70
Spring blinds, with tassels	18	...	...	2 80	30 40
Brass rings for blinds	36	...	...	40	14 40
Countersunk screws	108	...	...	85	0/0 90
Guides of blinds	...	36·	...	10	3 60
Rings with brass screws for the guides .	36	...	...	20	7 20
Stuffed buttons	18	...	...	30	5 40
Raw hemp	...	...	85·	50	42 50
Leather	...	...	90·	2 85	356 50
Workmanship of coachmakers	...	...	...	...	140
Ditto, glaziers, for the frame and coach . .	...	...	...	...	3 75
Painting	...	...	...	...	260
Conveyance to the line	...	...	...	...	8
					4932 70
Sundry expenses, use of tools, &c. at 20 per cent. . . .					986 55
Cost of a Berlin, exclusive of wheels, axles, grease-boxes, and guard-plates					5919 25
					= (£236 15*s.* 5*d.*)

*Minutes of Specification for the Construction and Fitting up of Forty Frames of Diligences for the Railway from Montpellier to Nîmes.**

1. The present specification comprises the construction, conveyance, and fitting up of forty frames of diligences, the frames (*limbers*) of which have been let to the proprietors of the Fourchambault Iron Works by the decision of M. ——, the Minister of Public Works, May 31, 1843.

The following parts are ordered and in course of manufacture at the present time:—

Axles mounted on wrought iron wheels.

Grease boxes, with the corresponding axle guards.

Suspension springs.

Buffing and drawing apparatus, with the springs.

The works comprised in the present specification are—

1st. The woodwork of the frames intended to support the bodies of the carriages.

2nd. All the iron-work necessary to protect the frames and unite them with the limbers, with the exception of the foot-steps which form a part of the contract for the bodies of the carriages.

3rd. The mounting of the limber and the frame at the manufactory, and afterwards on the line of railway at the stations of Nîmes or Montpellier, all expenses of transport being included.

2. The wood-work of the frame to be executed conformably to the annexed design, and to be composed of the pieces hereinafter enumerated.

Two side pieces, each 5^{m} 20 (17 feet) long, and 0^{m} 085 by 0^{m} 25 (3 inches by 10 inches) square section.

Two upper cross pieces, 2^{m} 20 (7 feet 3 inches) in length, and 0^{m} 09 by 0^{m} 25 (4 inches by 10 inches) square section.

Four intermediate cross pieces, each 2^{m} 00 (6 feet 7 inches) long, and 0^{m} 08 by 0^{m} 20 (3 inches by 8 inches) square section.

Four diagonal pieces, making together 8^{m} 40 (27 feet 7 inches) in length, and 0^{m} 12 by 0^{m} 06 (5 by $2\frac{1}{2}$ inches) square section.

One shoe under the springs 1^{m} 10 (3 feet 7 inches) long, and 0^{m} 35 by 0^{m} 08 (14 by 3 inches) square section.

Four sets of fittings to the stop pieces of turned-wood according to the pattern.

* These frames resemble those employed on the Rouen Railway.

Upon these several pieces being united, the frame will be 5^{m} 20 (17 feet) long between the outside faces of the upper cross-pieces, and 1^{m} 98 (6 feet 6 inches) wide between the outside faces of the side pieces.

3. All the wood-work to be of ash or oak, thoroughly dry, and of the best quality; all the pieces, more particularly the side pieces, to consist of solid timber, perfectly sound, regular in fibre, free from defective knots and broken fibres. The whole of the wood to be square, and have a square edge prepared and properly shaped on all sides, and united with the greatest precision, conformably to the rules of good coach-building.

The iron-work of the frame to be composed of the following pieces:

Of Iron filed and polished on all sides.

8 fork-shaped supports for the suspension springs, weighing together at least 60 kilogrammes, (132 lbs.)

Of Wrought Iron, and polished by the file.

4 screw rings for the safety chains.
4 squares of the diagonal pieces.
4 ditto sides of the frame.
8 drawing rods.
2 plate bands for the body springs.
2 tie pieces of the axle guards, each weighing 30 kilogrammes, (66 lbs.)

Screw Bolts with Heads.

32 bolts for the sides of the frame.
4 cross pieces.
8 acute-angled squares.
4 right-angled squares.
16 drawing rods.
30 foot-steps.
6 frames for the springs.
2 drawing rods to frame.
20 axle guards.

5. The weights of the 32 pieces and 122 bolts above enumerated are not given, with the exception of those which bear more than an usual strain. The value of the remaining iron-work is not regulated by the quantity of metal used, so

much as it is by the finish of the workmanship. It must be understood that this is to be executed conformably to the general features shown in the annexed design, although the weight is not specified, and in accordance with the detailed plan or model, which shall be approved of by the engineer.

6. The whole of the iron-work of the frame to be prepared with wood-charcoal, hammered, and of the first quality. It must be wrought with the greatest care, according to the models adopted by the engineers, and shaped as above described, according to the rules of coach-building.

7. The fork-shaped supports of the frame are to be joined to the suspension springs by leather straps disposed as shown in the annexed design. Every strap to be composed of seven leather bands of the best quality, sewn together with the greatest care, and forming a total thickness of 0^{m} 030 millimetres, (1 inch.)

8. Of the 40 frames constituting the contracts, 12 shall be furnished with a break, placed as shown on the plan marked § 2.

The manufacture and fitting of these breaks will be the subject of a separate specification.

The contractor shall be bound to perform the mounting of the frame and its joining with the wheels, axles, guard-plates and grease-boxes at the manufactory, and at the stations of Nîmes or Montpellier, according to the directions of the engineer, so that nothing shall remain to be done except placing the different bodies of the carriages and wagons (ordered by the directors) upon the frames.

10. The delivery and reception to take place at Nîmes or at Montpellier, all costs of transit being defrayed by the contractor.

On sight of the receipt (*proces-verbal*) of their provisional reception, nine-tenths of the amount of the contract to be paid to the contractor.

The remaining tenth to be retained as a guarantee for one year after the delivery. The pieces which may be injured or broken during this term, from any cause whatever, excepting a violent shock be proved to have taken place, shall be replaced at the expense of the manufacturer.

11. The frames, as before described, to be delivered as follows, viz.:—20 mounted frames within three months after the signing of the contract; 10 frames per month after the first delivery.

12. In case of non-compliance with the above conditions within the prescribed periods, 10 per cent. on the contract to be retained as indemnity from the contractor.

The contractor shall, moreover, be subject to the clauses and several conditions imposed on contractors of "Bridges and Highways," and joined to the

circular of M. the Director-General of Bridges, Highways, and Mines, dated 25th August, 1833, in every respect, provided such is not inconsistent with the present specification.

*Minutes of Specification for the Construction and Fitting up of the Bodies of the Passenger Carriages and Wagons on the Railway from Montpellier to Nimes.**

1. The present specification comprises the construction, conveyance, and fitting up of the bodies of carriages and wagons intended for the service of passengers on the railway from Montpellier to Nîmes—namely:

Eight carriages of the first class (*berlines*), with closed windows.

Ten ditto, of the second, or covered diligences, with closing windows.

Fourteen ditto, of the third class (*char-à-banc*), covered, but not enclosed.

Six baggage wagons.

2. The limber and frame-work of the carriages are executed according to special specifications and by separate contracts. The general description of the framing, with the necessary directions for its junction with the bodies of the carriages shall be remitted to the contractor of the present, in order that the final mounting of the carriages and wagons may not present any difficulty.

SECT. I.—*Carriages of the First Class, or Berlines, with Close Windows.*

3. The general dimensions of the first-class carriages to be according to the plan, and as follow:—

Length between outside faces 5^{m} 20 (17 feet); width between the outside faces to be 1^{m} 98 (6 feet 6 inches), exclusive of the swelling-out parts.

Height between the bottom of the body and the canopy 1^{m} 60 (5 feet 3 inches).

Height from wooden seat to floor 0^{m} 35 (13 inches).

Length of each end compartment from outside to outside 1^{m} 70 (5 feet 7 inches).

Interior length of middle compartment 1^{m} 80 (5 feet 11 inches).

The dimensions of the details to be conformable to the subjoined plan and to the drawings which shall be approved and signed by the engineer.

4. The bodies to be constructed of hard wood; the lower side-pieces, corner-pieces, and all the larger pieces of the framing of the seat to be of ash. All the

* The models were nearly similar to those employed on the Rouen Railway.

wood to be perfectly dried and of the best quality, prepared, shaped, and joined according to the rules of coach building.

The exterior panels to be of plate-iron.

The interior of each body to be strengthened by at least sixty squares of iron fastened by screws. As the plan does not show these squares, it must be understood that each of the joints of the several parts of the framing shall be strengthened by an iron, according to the best practice of coach-building. The iron-work of the doors to be executed with the greatest care; the double hinges and the lap-over pieces to be of copper, and fastened by screws, the mode of closing to be by folding doors with springs.

Each door to be provided with a copper handle, and a counter one, conformably to the general indication of the subjoined design and to the model which shall be approved by the engineers. The six sash-frames of the doors and panels of each body of a carriage to be fitted with Bohemian glass, or with double glasses, perfectly flat, without specks, flaws, or defects. The frames of the two end compartments to be of hard wood and varnished; those of the middle compartment to be formed of mahogany. The roof to be covered with two sheets of red copper 7-8ths of a millimetre (·034 of an inch) thick, lapped and soldered together at the middle of the compartment.

Each of the two seats raised on the roof to have branches, body guards, and elbows, and six foot-steps for mounting, formed of iron, according to the plan.

The roof, moreover, to be surrounded by an iron railing, according to the design.

The body to be prepared, painted, and varnished with coach varnish with the greatest care, and with stripes in the panels if there is room, of the colour and shade to be chosen by the directors. The manufacturer of the bodies shall further be bound to paint the body in three coats: the first with white lead and oil for the wood, and *minium* for the iron. The exterior faces of the lower side-pieces and the outside cross-pieces to be varnished with coach-varnish.

The body to be accompanied by two boards, each of them being constructed as follows:—

Five pieces of wrought-iron with two branches, with palette of strong plate-iron 8 millimetres (·314 of an inch) thick, conformable in other respects to the model which shall be remitted to the contractor. A platform of oak, planed on every side, with the edges rounded, being 4^{m} 20 (13 feet 9 inches) long by 0^{m} 20 (8 inches) wide, and 0^{m} 035 (1·3 inches) thick.

The contractor shall be bound to join the chains and drawing-rods, shown in the plan, to each body, as follows:—

Four safety-chains, weighing each 6 kilogrammes, (13 lbs.)

Two draw-rods, each consisting of two long links with nuts, united by a screw furnished with a ball-handle, to be made conformably to the design which shall be remitted to the contractors, and each weighing 12 kilogrammes. (26 lbs.) The whole to be of iron prepared by charcoal, of the first quality.

5. The body of the middle of the carriage to be fitted up with blue cloth dyed in the wool, of a quality at least equal to that of the best furnished carriages of the railroad *du Gard*, or those in the vicinity of Paris.

The two back cushions, the mattresses above the back cushions, the elbows, and the cushions of the seats, to be stuffed with hair of the first quality, and of the substance indicated in the design, pointed with woollen buttons, and mattressed with stuff under the blue cloth covering.

The canopy to be spread with cloth of the same shade as the furniture.

The floor to be inlaid and covered with Mocadoes carpet. A woollen galloon of the first quality of pattern, 6 centimetres (2·3 inches) wide, is to be fixed round the upper ceiling as an edging, and the cords of each sash are also to be furnished with it. The cords of the sashes to be lined with leather, and pointed in two rows, the ends ornamented with woollen fringes, with collar above. Galloon is to be adjusted to the cushions, doors, pilastres—everywhere prescribed by usage, and sewed and turned down.

The Berlin to be furnished with six blinds of taffety, with silk tassels and strings, and the rollers of the centre sashes to be of ivory.

6. Each of the two bodies forming the end compartment to be furnished with blue and white ticking, and the various parts to be stuffed of the substance indicated in the plan, and with the same care as the Berlin.

The canopy to be spread with ticking, like that of the furniture.

The floor to be inlaid, (*garni en parquet.*) The cords of the sashes to be of galloon, united and pinned, of the first quality, and 55 millimetres (2 inches) wide, lined with leather pointed in two rows, and ornamented with woollen fringes with collars. Galloon to be adjusted for the sewing, and as edging round the upper canopy, and to the cushions, doors, and pilastres, and as before described, Art. 5.

Each compartment of the carriage to be provided with 6 blinds of linen-cloth, with ordinary strings, and the rollers of the sashes to be of copper.

Sect. II.—*Second-class Carriages or Diligences covered in, with closed windows.*

When the original specification was drawn up, it comprised two classes of carriages only, but the government subsequently adopted as a general measure on all railways, the establishment of three classes of carriages. A fresh order, dated 25th January, 1844, was therefore made for the construction of ten carriages of an intermediate class, covered and enclosed with windows.

These carriages were comprised in a single contract under the approval of the upper administration, and constructed as follows.

The body of the carriage of the second class shall be in all respects conformable to that of the third class described in Articles 7 and 8 above, except that it shall have panels and glazed doors, as indicated in the folding plate, containing an elevation of the design, and numbered 54.

The glazed compartments, further, shall be conformable to those of the Berlins at the ends of the first class carriages, except in their dimensions, and be furnished with similar blinds.

The wooden seats shall be lower by 10 centimetres, (4 inches), than those of the third class carriages, and covered with cushions stuffed with hair and furnished with *ticking* quilting of the thickness of 0^m10 (4 inches.)

Sect. III.—*Third-class Carriages, (Char-a-bancs) covered in but not enclosed.*

7. The general dimensions of the bodies of the carriages of the third class to be conformable to the design as follows:

	metres.	ft. in.
Length between the two outside faces	5·20 =	(17 0)
Width, ditto ditto	2·30 =	(7 6)
Length from axis to axis of each of the four compartments	1·30 =	(4 3)
Height of wooden seat above the floor	0·45 =	(1 6)
Height from floor to the ceiling	1.60 =	(5 3)

The dimensions of the details, moreover, to be conformable to the annexed design, and to the drawings which shall be approved and signed by the engineers.

8. The body to be constructed of hard wood, the lower side pieces, corner pieces, and the larger parts of the frame-work to be of ash, the smaller pieces and seats, of oak or ash. All the wood to be perfectly dry, and of the best quality, prepared, planed, and joined, according to the rules of coach-building.

The parts of the lower side pieces projecting 5^m15 (16 feet 10 inches) on each side of the shaft pieces of the frame, are to be supported, in the first place, by the projecting portions of the extreme iron pieces, and afterwards by three wrought iron brackets placed at intervals on each side according to the plan.

The outside panels to be of plate-iron.

The interior of the body to be strengthened by at least 80 squares or plates of wrought iron, fastened by screws. As the plan does not show these squares or plates, it is to be understood that each of the joints of the several parts of the framework shall be strengthened by a square or a nut-bolt, according to the best rules of coach-building.

The iron-work to be executed with the greatest care. Each door to have two ordinary hinges, hasp, spring, folding door, brass handle, according to the general plan, and to the particular model approved by the engineers.

The carriage to be open at the sides and divided into four compartments as indicated in the plan by means of wooden partitions surmounted by columns of polished iron.

The roof to be covered with two sheets of red copper, seven-tenths of a millimetre (·027 of an inch) thick, joined and soldered together at the middle of each compartment.

Each of the two seats of the roof to be placed as shown by the plan, with branches, body guards, and foot boards of iron as described in Article 4.

The bodies to be prepared, painted, and varnished with coach varnish on the outside with the greatest care, and of the colour and shade chosen by the directors.

Lastly, as there is no furniture, the contractor shall be bound to pay particular attention that all the inside pieces and panels, floor, upper canopy, seats, &c., be perfectly even and well joined. All the inside faces, excepting the floor, to be painted with oil in two coats with a colour which shall be pointed out as before.

The contractor of the bodies shall, besides, be charged with painting the frames on the conditions announced in Article 4.

Each body to be accompanied by two foot-boards composed as follows:—4 pieces of wrought iron with two branches, with step formed of plate iron, 8 millimetres (·314 of an inch) thick, each weighing at least 11 kilogrammes (24lbs), and conformable, besides, to the model to be transmitted to the contractor; a platform of oak, planed on all sides with rounded edges.

The contractor shall be bound to join to each body four safety-chains and

two draw-rods, with screws and nuts according to the conditions mentioned in Article 4.

Sect. IV.—*Baggage-Wagons.*

The general dimensions of the baggage-wagons to be conformable to the plan: namely—

	metres	ft. in.
Length between outside faces	5·20 =	(17 0)
Width ditto, ditto	2·30 =	(7 6)
Height from floor to dome, measured outside .	2·0 =	(6 6)

9. The dimensions of the details, moreover, to be conformable to the subjoined plan, and to the drawings which shall be approved and signed by the engineers.

10. The body of the wagon to be constructed of hard wood, the lower side pieces and corner pieces of ash, the other pieces of the framing of oak or ash. The panels to be of walnut or oak.

All the wood to be perfectly dry, and of the first quality, prepared, planed, and joined according to the rules of coach-building.

The interior of the body to be strengthened by at least 60 squares, or bolts of wrought iron, according to the conditions of Article 8.

The diagonal pieces of the outside panels to be further fastened to the side planks by wooden screws, as shown by the plan.

A large door to be made at each side of the wagon, with two leaves and four small doors. These doors and openings to be provided with their squares, iron-work, and hinges, as shown in the plan. They must all be shut by locks, with spring-folding doors, of the model approved by the engineers. The lower doors to close in the dog-boxes at the bottom of the wagon, conformably to the plan. They are to be pierced with a round hole, for the purposes of ventilation, and to be furnished with a metallic plate. The roof to be covered with two sheets of copper, and provided with two seats, with footsteps in every respect like those of the second class.

All the outside faces to be prepared and painted with oil, and in two coats, of a colour to be chosen by the directors.

The body to be painted, both iron and wood, like the carriages, as described in Article 4, excepting that all the coats shall be painted in oil without varnish. Each body to be accompanied by six pieces of iron, with two branches for foot-boards, with plate iron step, each weighing at least 11 kilogrammes (24lbs), and conformable to the model remitted to the contractor.

The contractor shall join to each body four safety-chains and two draw-rods, with nuts and screws, as described in Art. 4.

Sect. V.—*General and Particular Conditions.*

11. The contractor shall be bound to mount the carriage, and unite it with its frame, at the stations of Nîmes or Montpellier, according to the intention of the engineer, and as shall be directed.

12. The delivery and reception to take place at Nîmes or Montpellier, all costs of transport being made at the expense of the manufacturer.

On sight of the *procès verbal* of the provisional reception, then nine-tenths of the amount of the contract shall be delivered to the contractor.

The remaining tenth shall be retained as a guarantee for one year after the delivery. All the pieces which shall be damaged or broken by any cause whatever during this period, excepting a violent shock be proved, to be replaced at the cost of the manufacturer.

13. The carriages, as above described, for each contract, shall be delivered as follows—viz., Half the number to be constructed before the 10th of May, 1844, and the remainder before the 1st of June following.

14. In case of non-execution of the above conditions within the time prescribed, a drawback of 10 per cent. shall be made from the manufacturer as indemnity.

15. The manufacturer to be subject also to the clauses and general conditions imposed on contractors of Bridges and Highways, joined to the circular of M. le Directeur-General of Bridges, Highways, and Mines, dated August 25th, 1833, in every respect, unless specifically inconsistent with the present contract.

Nîmes, 10th December, 1843.

STATEMENT OF PRICES OF CARRIAGES.

1st. Frame and Wheelwork.

	frs.	
Two pair of iron wheels, with their axles	1150	
(This price will vary according to the diameter of the axles, and of the tires of the wheels.)		
Buffing apparatus and drawing do., with their springs, about	1000	
Frame, exclusive of the foot-boards, and the drawing rods and chains	1300	
Four springs, weighing 55 kilog. each (121 lbs.), making together 220 kilog. (485 lbs.) at 2 frs.	440	
Four grease boxes, at 23 fr. each	92	
Four axle-guards, weighing 14 kilog. (30 lbs.) each, making together 56 kilog. (123 lbs.) at 1 fr. 50 c.	84	
Total . . .	4066	
Say . . .	4000	= (£160 0 0)

2nd. Body of the Carriage.

Price of Public Contract, 23rd February, 1844.

	Frs.	£.	s.	d.
Body of a First Class, including foot-boards, drawing-rods, and chains	4800 =	(192	0	0)
Body of a Second Class do. do. . .	3500 =	(140	0	0)
Body of a Third Class do. do. . .	2800 =	(112	0	0)
Baggage Wagon do. do. . .	2400 =	(196	0	0)

3rd. Mounted Carriages.

First Class carriage, including foot-boards, drawing-rods, and chains	8800 =	(352	0	0)
Second Class do. do. . .	7500 =	(300	0	0)
Third Class do. do. . .	6800 =	(272	0	0)
Baggage Wagon do. do. . .	6400 =	(256	0	0)

*Minutes of Specification for the Construction of Twelve Breaks for Second Class Carriages and Baggage Wagons of the Railway from Montpellier to Nîmes.**

1. The present specification comprises the supplying and fitting up of twelve breaks for the use of the carriages and wagons of the Railway from Montpellier to Nîmes.

2. Each break to be made conformably to the general design, traced in blue, on the drawing marked § 4, and according to the details of construction of the drawing marked § 2. To consist of the following pieces—namely:

Supporting Pieces of Polished Iron, turned or tapped.

	Kilogs.
Four hinges for the break apparatus, weighing . . .	4·0
Four rods, formed with joints to connect the ironwork of the blocks of break to the levers, making together	14·0
One lever axle (*fork-shaped*)	3·50
One lever support	5·0
Screw nut for spindle and crank rod	10·0
One supporting rod	3·0
Fifty-one different turned bolts	26·0
One crank	4·0
Four supports of the cross pieces, fixed to grease boxes,	8·0
Total weight . .	57·50 = (127 lbs.)

Polished and turned pieces of Iron for common purposes.

	Kilogs.
Four pins or blocks of break, weighing	10·53
Two levers, fixed behind the break	9·0
Lever transmitting the power	7·20
Rod joining the crank lever to the lever fixed on the axle	11·0
Total weight . .	37·73 = (83 lbs.)

* The models were nearly similar to those of the Rouen Railway.

Iron wrought and partly filed.

	kilogs.
Two cross-pieces of flat iron fastened to the grease-boxes, and supporting the apparatus, weighing together	68·48
Four pins, or wooden blocks, each in two parts . . .	30·56
One axle to break	48·36
Total weight . .	147·40=(325 lbs.)

3. All the iron work to be of Bourgoyne or Berry iron, of the first quality, well hammered. It is to be forged with the greatest care, according to the patterns approved of by the engineers, and is to receive the pattern thereon designed conformably to the best modes of constructing machinery.

4. The drawback to be determined by counter-weighings, the following prices being applied for the different classes of iron-work. No payment to be made to the manufacturer for any excess of weight arising from an increase of dimensions unauthorized by the engineers.

5. The contractor to supply four blocks to each break of elm wood, to be perfectly compact, free from broken fibres, prepared and cut with care, according to the plan which shall be remitted by the engineers.

6. The contractor is bound to mount the breaks and the appendages with the frames and bodies of the carriages and wagons, according to the plans of the engineers, at the stations of Nîmes or Montpellier.

7. The contractor shall receive nine-tenths of the amount of the contract immediately after the fitting up. The remaining tenth to be retained as a guarantee for six months after the fitting. Those pieces which shall be injured or broken during this term, to be replaced at the expense of the manufacturer, always excepting the elm blocks, which shall be received finally upon their being fitted up.

8. The breaks comprised in the present specification to be finished before April 15th, 1844, under penalty of a drawback of 10 per cent. on the price, as indemnity.

9. The manufacturer to be further subject to the clauses and general conditions imposed on contractors for bridges and highways, and joined to the circular of M. the Director-General of Bridges, Highways, and Mines, dated 25th August, 1833, in every respect, unless specifically inconsistent to the present specification.

Statement of Prices.

		frs.	
No. 1.	Price of iron per kilogramme, for supporting purposes before stated, of polished iron, turned or tapped	3	
2.	Price of iron per kilogramme, polished, for common purposes for the pieces before described	2	50
3.	Price of iron per kilogramme, wrought, and partly filed, for the pieces before described	1	75
4.	Price of each elm wood block	5	

Detailed Estimate.—Price of a Break, including the Fitting up.

		frs.	
No. 1.	Polished iron, turned or tapped, for supporting pieces, 57·50 kilogs. at 3 frs.	172	50
2.	Iron polished and turned, for common purposes, 37·73 kilogs., at 2·50frs.	94	32
3.	Iron wrought, and partly filed, 147·40 kilogs. at 1·75fr.	257	95
4.	Four elm wood blocks, at 5fr.	20	
		544	77
	Mounting the 12 breaks.	6537	24
	Add for sundry expenses and improvements,	462	76
	Total sum for 12 breaks.	7000	(£280.)

Minutes of Specification for the Construction of Goods Wagons for the Railway from Strasbourg to Basle.

WOOD.

ART. 1. The wood employed in the construction of the wagons to be of ash, provided it can be procured, otherwise of oak, which must have been felled at least two years previous, and be of good quality. The pieces employed to be straight in the fibre, and without knots. They must be correctly squared, free from sap-wood, of the exact dimensions marked on the annexed plans, and free from all blemishes which may injure either its strength or wear, such as shakes, dry knots, or sap.

Iron.

Art. 2. The iron also to be of the best quality. The contractor must state in his tender whence it is obtained, and be prepared to prove this by the invoices, if required by the company. The iron bars are to be proved before being used, and the whole of the pieces manufactured. These trials to be made at the cost of the manufacturer, and such pieces or bars that are found to be of inferior quality will be rejected, and every piece that is defective either in quality or form, or that does not agree with the specified dimensions, shall be broken and destroyed, without the contractor being entitled in any case to be paid for them.

Adjustment of the Pieces of the Wagons.

Art. 3. The whole of the pieces forming similar parts shall be matched—i.e., made so that they can be used indiscriminately one for the other without any alteration being necessary. The threads of the bolts shall fit the worms of the screws, and be of the size indicated by the models provided by the company. Steel patterns will be remitted for this purpose. The whole of the nuts to bolts of similar calibre must be capable of being applied indiscriminately for the whole, and the latter must be of the exact dimensions required, and conformable to the models. The whole of the pieces of the wagon, including the wheels, axles, grease-boxes, axle-guards, springs, locks, &c., which do not strictly fulfil the condition of matching as described in this article will be rejected.

Fitting-up.

Art. 4. The several joints of the wood must be executed with the greatest care, without any loose play being allowed. They are to be painted with thick oil at the time of being finally fixed, together with all parts which are in contact with iron as well as the iron itself. The bolts to fit accurately into the holes prepared for them, and to be covered with paint like the former. The *line of draught* to be determined by a line traced exactly along the axis of the frame. The most scrupulous care must be used in placing the axle-guards. The employment of a guage will not be considered sufficient; their position on each frame must be set out geometrically, by lines perpendicular to the axis of the line of draught. The bolts which secure them to the lower side-pieces must be turned throughout their entire length, and to enter with equal friction both into the wood as iron.

Wheels.

Art. 5. The wheels to be constructed according to the dimensions and pattern remitted to the contractor. Those mounted on the same axles to be precisely equal in diameter. They are to be wedged up, so as to lie in a plane perpendicular to the axle and concentric with the gudgeon, in order to accomplish which they are not to be turned on the outside until mounted on the axle.

The spokes to be scoured on the outside, and the tire formed of the prescribed dimensions, and hammered smooth and even on the inside. The contractor must state the source from whence he intends to obtain the tires. They must be at least two centimetres (·787 of an inch) thick at those parts where the countersunk holes are prepared to receive the rivets.

Axles.

Art. 6. The axles will be furnished by the company when the contractor is ready to receive them—namely, 10 axles before the 1st April next, 10 from the 1st to the 15th April, and the remainder at 5 per week, beginning from the 15th April. If the company cause any delay in the work, it is hereby agreed that the contractors are authorized to exceed the time for the delivery of the wagons, as fixed by Article 16, by an equal period.

Axle Guards.

Art. 7. The axle guards to be perfectly smooth, the interior in which the grease box slides to be carefully prepared by a planing machine, also the outside portions against which the edges of the grooves of the grease box rub, so that the rubbing part in the grease box may be made of less thickness than the rest of the guard. The holes of the axle guards to be pierced according to a pattern, in order that they may be changed without fresh holes being required to be pierced in the wood.

Grease Boxes.

Art. 8. The grease boxes to be composed of soft cast-iron of good quality, the parts sliding in the axle guard being adjusted by a planing machine. The joint separating it into two parts to be also carefully adjusted; the bearings to be composed of hard brass, without any composition of zinc, and to be carefully adjusted in the grease boxes. The adjustment of the bearings and the boxes

to be made by means of moulds, so that the whole of the bearings may fit any of the boxes.

Springs.

Art. 9. The plates forming the springs, excepting the principal plates, to have a section of 75/7, and to be tapered with the utmost regularity. They must be of precisely similar width, and be prepared with a file or a grind-stone, so as to be in contact throughout their entire length. The springs to be tried with a weight of 2000 kilogrammes (4410 lbs.), under which they must not bend more than 70 millimetres ($2\frac{1}{2}$ inches), and recover their position on the weight being removed, without losing more than one centimetre (·39 of an inch) of their original shape. They are, moreover, to be conformable in curvature to a pattern which shall be sent to the contractor.

Superintendence.

Art. 10. The railway company will send one of its agents to superintend the construction of the wagons, and to examine the materials employed in their execution. This agent will inspect the materials in the rough and the finished pieces; he is to have the right of making observations to the workmen on every piece, and upon every matter which does not fulfil the condition prescribed in the present specification; he will also verify the setting out of the mounting of each wagon, as well as the mounting itself.

Art. 11. The examinations made during the work by the agent above referred to, as well as the partial reception of any manufactured pieces, is not to prevent those defective from being rejected at the final completion referred to in next article, or any pieces that are badly fixed from being replaced.

Reception.

Art. 12. When the wagons are finished and mounted, they will be finally received, upon a special request addressed by the contractor to the directors, previous to their being painted. Every piece which does not, at this delivery, fulfil the prescribed conditions to be replaced at the cost of the contractor.

Guarantee.

Art. 13. The contractor is to be responsible for a period of one year, for all pieces which may be broken in consequence of faults arising from bad construction, or the use of materials of bad quality. When the wagons are brought into use,

every piece that breaks or becomes injured in consequence of faults of the above nature, as well as such parts which may become fractured in consequence of a piece proving bad, are to be replaced by the contractor. This is to be done immediately upon being required by the directors, and the question respecting liability to the expense of same, in case of dispute, to be decided afterwards. If the contractor does not cause the repairs to be made directly, the railway company will cause them to be made in their own workshops, and the contractor shall pay the expense of the same, provided it be proved that the accident has arisen from a defect in the form or quality of the part broken or damaged.

Delivery.

Art. 14. Upon the wagons being completed, they are to be delivered accordingly at the Koenigshoffen station.

Period of Delivery.

Art. 15th. The wagons to be delivered as follows—viz., Ten before the 30th of April, and the remainder by the 31st of May following, at the latest.

Drawback for Delay.

Art. 16th. For every day's delay in the delivery of the wagons, undertaken by the contractor, a sum of fifty francs shall be withheld, without the excuse of the delay being caused by the rejection of any parts of the wagons (by the agents of the company) being in any case allowed. This drawback to be allowed as indemnity to the company for the losses it may sustain in consequence of the imperative demand for this article.

Payment and Provision for Disputes.

Art. 17. The payments to be made in the month following the delivery, in bills on Paris, payable at one month's date, excepting one-twentieth of the total amount of the contract, which will be retained as a guarantee during the time which the contractor is responsible for his work, in virtue of Article 10.

Every dispute, of whatsoever nature it may be, which may arise between the contracting parties during the progress of the works, or at the time of the reception, or, lastly, during the term of guarantee, the parties mutually agree to carry before the tribunals of the Department of the Seine, where the office of the company is situated.

Mulhouse, 23*rd Feb.* 1843.

Estimate of a Goods Wagon of the Strasbourg and Basle Railway.

DESCRIPTION OF ARTICLES.	Dimensions.	Weight.	Price.	Sum.
	millimet.	kilog.	frs.	frs.
2 Wrought-iron axles	...	252·	205 each	406 50
4 Wheels	...	1036·	90 0-0 k	932 40
4 Guard plates	...	112·50	160	180
2 Traction rods, with hooks partly threaded, and nuts . .	...	33·80	160	54 8
1 *Tendeur*	...	9·30	200	19
4 Plates, 2 being partly tapped to receive the traction rods, and to fix them to the springs	...	8.	200	19
4 Guides to conduct the traction springs	...	27·60	120	16
2 Guides for traction rods	...	9·20	120	33 12
4 Buffer rods, pierced with a mortice at one end, and threaded at the other, with 4 nuts and 4 keys . . .	...	·90	160	11 14
4 Plate-iron caps to receive the wooden buffers, with their circles	...	13·30	120	144
4 Wooden buffers	...	...	1 piece	
2 Rods for securing the grease boxes to the guard plates .	...	21·60	160 0-0 k	15 96
8 Stirrup pieces for fixing the suspension springs to the grease boxes	...	6·50	200	4
2 Stirrup pieces for uniting the centre longitudinal piece with the second cross piece	...	3·	200	34 56
8 Plates for guiding the buffer rods and preserving the cross pieces	...	7·60	160	13
24 Ferrules, of which 20 are for the cross pieces, and 4 for the lower side pieces	...	16·50	160	6
1 Flat iron band for the box	...	23·	120	12 16
4 Squares for the angles of the body	...	5·30	160	26 40
2 Safety chains, with hooks and claw for fixing it to the lower side pieces, and 2 single claws for hooking the chains	...	22·	120	27 60
4 Coverings to grease boxes	...	...	3 pieces	12
20 Bolts for guard plates	20	12·	180 0-0 k	19 20
8 Bolts for securing the traction springs between the springs	15	4· 5 0	160	7 20
8 Bolts for securing the two upper guides to the cross pieces	15	2·60	160	4 16
8 Bolts with countersunk heads for maintaining the two lower guides to the centre piece	15	2·	160	3 20
8 Bolts for fixing the two guides of the traction rods . .	13	2·70	160	4 32
4 Bolts for uniting the lower side pieces to the diagonal pieces	15	2·00	160	3 20
2 Bolts for uniting the diagonal pieces to the centre piece,	15	1·60	160	2 56
4 Bolts ditto to the third cross piece,	15	2·40	160	3 84
3 Bolts for uniting the lower cross piece to the centre piece, and to the side pieces.	15	2·10	160	3 36
8 Bolts for fixing the lower side pieces to the back of the cross pieces, the diagonal pieces and the frame together,	15	8·	160	12 80
14 Bolts for fixing the body to the cross pieces	15	8·40	160	13 44
8 Bolts for securing the cast-iron supports of the suspension springs to the lower side pieces, and the lower side pieces and the cross piece together	15	4·50	160	6 88
8 Bolts for fixing the safety chains to the lower side pieces,	15	2·60	160	4 48
16 Bolts for fixing the buffer guides	15	5·60	160	8 96
8 Bolts for fixing the rods employed to secure the grease boxes in the guard plates	13	0·80	225	1 80
24 Bolts, with countersunk heads, for fixing the wooden buffers to the plate-iron caps	12	2·20	225	4 95
10 Hooks	15	6·40	160	10 24
Carried forward	...	...	...	2082 23

ESTIMATE—*continued.*

DESCRIPTION OF ARTICLES.	Dimensions.		Weight.	Price.	Sum.
			kilog.	frs.	frs.
Brought forward	... ...	...	... ...	... ...	2082 23
176 Wooden screws, T P 27/45, for fixing the guide plates of the buffer rods and the ferrules of the lower side pieces and cross pieces and the flat irons to the frame	... ...	...	Dozen	40	5 87
140 Wooden screws, T P 29/75, for fixing the planking to the cross pieces and to the frame	... ...	...	... ...	75	8 75
56 Wooden screws, T D 29/75, for fixing the squares to the angles of the body and the stops of the wheels to the lower side pieces .	... ...	...	... ...	1 49	6 96
STEEL.					
4 Suspension springs	... ...	...	149·	250	872 50
2 Traction and buffer springs	... ...	...	95·	250	237 50
CAST IRON.					
4 Adjusted grease boxes	... ...	...	83·	80	66 40
4 Guide supports for guiding the buffer springs against the buffer rods	... ...	...	13 20	60	7 90
4 Guides for the buffer rods	... ...	...	36.	60	21 60
8 Supports for the suspension springs	... ...	...	12·	55	6 60
8 Stops of wheels	... ...	...	19· 20	55	10 36
BRASS.					
4 Adjusted brass squares	... ...	...	6· 40		28 80
				450	
ASH TIMBER.					
	Length.	Thickness.	Cube.		
2 Lower side pieces	5·020	100-220	0·220880		
4 Diagonal ditto	2·500	100-100	0·100000		
1 Longitudinal centre piece	4·700	100-100	0·047000		
2 Outside upper cross pieces	2·560	100-100	0.051200		
2 Ditto lower ditto	2·400	100-180	0·086400		
5 Cross pieces	2·560	100-200	0·056000		
1 Ditto to fasten the diagonal pieces and the lower side pieces	2·400	100-100	0·024000		
DEAL.					
		m.	0·785480	140	109 96
2 Large side pieces	4·700	80 180	0·067680		
2 Small do	2·400	80 180	0·034560		
			0·102240	40	4 8
2 Planks of 0.060 metre, (2·3 inch) in thickness.	4·560	0·250	2·280	3 50	
6 Ditto 0.040 ditto (1·5 inch) ditto . . .	4.560	0·290	7·930	2 50	7 90
					19 82
50 Days' workmanship in fixing the iron work and details	... ...	...	per day	3	150
Total	... ...	...	... ...	... ...	3650·49
					(£146 0*s.* 4½*d.*)

Estimate of Coal Wagon for the Great Comb Mine Company, and the Gard Railway.

Prime Cost.

	frs.	frs.
1stly. Mounting	329	
2ndly. Iron work, complete ...	220	699, say 700 = (£28.)
3rdly. Carpentry and planking	150	

1stly. *Mounting.*

		frs.		frs.	frs.	£	s.	d.
1 Wheel	Cast iron 175 kils. (386 lbs.) at 0·376fr.	4·750						
	For tire	0·666		= 65·566, say 65	60=(2	12	6)
	Turning	0.150						
1 Grease box, 7 kilogs. (15lbs.) at 0·30fr.					2	10=(0	1	9)
1 Axle	Iron (ordinary iron of 3^c round, $1{\cdot}915^m$ (6ft. 3in.) long, 75·73 kils. (166lbs.) at 0·32fr. the kilog. ...	24	24					
	Making (forging)		50	= 27 74, say 27	75=(1	2	2)	
	Turning	2						
	Ditto	1						
Mounting	Workmanship	0	75					
	Making pin, 1 kilog., at 0·25fr. the kilog.	0	25	1	25=(0	1	0½)	
	Square iron for pin, 0·50 kilogs., at 0·50fr. the kilog.	0	25					

Prime Cost of Mounting complete.

4 Wheels at 65·60fr. each	262	40	
4 Grease boxes, at 2·10fr. ditto	8	40	= 328 80, say 329 = (13 3 2)
2 Axles, at 27·75fr. ditto	55	50	
2 Ditto mounted, at 1·25fr. ditto	2	50	

2ndly. *Iron work.*

	frs.	
4 Grease box straps	20	
1 Break lever	23	
1 Ditto plate	2	
2 Bolts for ditto	1	20
1 Break axle	2	30
1 Support of ditto, 9·10 kilogs. at 0·35fr. = 3·185fr.	3	20
2 Bolts for ditto	3	
2 Traction rod plates	34	
6 Bolts for ditto	5	70
4 Safety hooks	13	60
4 Bolts for ditto	2	
4 Ferrules and 8 nails	10	30
1 Lining for bottom	31	20
6 Bolts for fastening ditto	2	10
1 Break guide, 1·60fr.; 1 break chain, 0·40fr. ...	2	
1 Screw ring and pin for fastening bottom	1	50
2 Ditto for small chains and drawing plate	2	40
Carried over	159	50

	frs.	
Brought forward	159 50	
4 Squares	8	
29 Square bolts (16 for the squares, 6 for the hollow beams, and 7 for the end of side)	9 70	
4 Upper rods, 3·60fr., and 16 bolts for ditto, 3·20fr.	8 80	
1 Pin for break axle	10	
1 Pin for screw ring for fastening bottom	30	
8 Pin irons	10	
2 Bolts, No. 8, 7·40fr., 2 ditto, No. 9, 10·80fr. ...	18 20	
1 Drawing chain with plates	8	
2 Safety chains...	6	
		frs. £ s.
	218 70,	say 220=(8 16)

3rdly. *Carpentry and Planking.*

Carpentry. (Oak Timber.)

	m.	m. q.
2 Stop pieces ... ... each	3·00 × 0· 19 × 8· 16	= 0·1834
2 Inside cross pieces	1·12 × 0· 23 × 0· 14	= 0·0721
2 Outside ditto	5·12 × 0· 19 × 0· 14	= 0·0595
2 Intermediate ditto	0·35 × 0· 19 × 0· 14	= 0·0175
14 Uprights	1·50 × 0·105 × 0·085	= 0·1801
2 Hollow framed end pieces	2·10 × 0· 14 × 0· 09	= 0·0693
2 Ditto, side pieces	2·75 × 0· 14 × 0· 06	= 0·0693
1 Bottom flap (plank)	0·65 × 1· 15 × 0· 05	= 0·0546
1 Break	0·15 × 0· 14 × 0· 05	= 0·0143
		0·7287
	Loss 1-10th	0·0728
		frs.
	Total cube	8·80 at 100 = 8C

Planking 0·27^{m} (1in.) thickness (poplar, aube, and northern fir.)

The two sides of the wagon and the two ends, in all 10^{m}, at 2·25fr.	22·50
Making	47·50
Cost of carpentry and woodwork	150·00=(£6.)

A Lift for the Transport of Coke.

The lifts were originally formed of oak, and cost 85frs. (£3 8*s.*) We, however, prefer fir for their construction, as it is lighter. The lift made of it lasts as long, and costs only 70fr. (£2 16*s.*)

Cost (*Oak Carpentry*).

	frs.	frs.	£ s. d.
Iron work	27 40	= 84·40, say 85	=(3 8 0)
Carpentry and nailing	57		

Cost (Fir Carpentry).

	frs.	frs.	frs.	£	s.	d.
Iron work	27 40	= 69·65, say	70 = (2	16	0)	
Carpentry and nailing	42 25					

Details of Iron work.

	frs.	frs.	frs.	£	s.	d.
4 Upper rods	5 60	= 27·40 at 1fr.,	27·40 = (1	1	10)	
16 Bolts for ditto	3					
8 Squares	7 60					
32 Bolts for ditto	6 40					
16 Ditto for fixing the lift upon the wagon	4 80					

Details of Oak Carpentry.

	m.		
4 Hollow framed pieces, each	2·70 × 0·055 × 0· 09 = 0·053	$= \overset{m\ q}{0{\cdot}167}$	
4 Ditto	2·06 × 0·055 × 0· 09 = 0·044		
8 Posts	0·70 × 0· 09 × 0· 07 = 0·035		
8 Discharging pieces ...	0·90 × 0· 09 × 0·055 = 0·035		
	Loss, 1-10th	0·016	
		0·183, say 0·18 at 100 =	18
Planks 6·70^{m} at 1·50fr.			18
Making			10
Nails and spikes, also sundry expenses			4
			50 = (2 0 0)

Details of Fir Carpentry.

	m.		frs.
4 Hollow framed side pieces	2·70 × 0·10 × 0·06 = 0·064	= 0·215 at 50 = 10·75	42 25 = (1 13 9½)
4 Do., end do....	2·05 × 0·10 × 0·06 = 0·050		
8 Posts	0·70 × 0·10 × 0·09 = 0·051		
8 Discharging pieces ...	0·90 × 0·10 × 0·07 = 0·050		
Poplar or Burgundy planks, 6·65^{m} at 1·50 = 9·99 = ...		10·	
Making (time of workmen, 18fr., tools, sundries, &c., 1·80)		19·80	
Nailing, 1·70 kilogs. (4lbs.) at 1fr. per kilog.		1·70	

Belgian Minutes of Specification.

The Minister of Public Works of Belgium put up to public competition, on the 24th February, 1841, the supply of 1500 wrought-iron wagon wheels, required in the construction of the railway works in course of formation, on the following conditions:—

			frs.	£ s.
ART. 1. Contract	1st, of 200	wheels, estimated at	188 each =	(7 10)
	2nd, of 200	"	"	"
	3rd of 200	"	"	"
	4th, of 200	"	"	"
	5th, of 200	"	"	"
	6th, of 250	"	"	"
	7th, of 250	"	"	"

ART. 2. These wheels are to be formed of wrought-iron, and manufactured according to the model deposited at the Railway Depôt at Malines; the jointing to be set out exactly on a constant diameter of 86 millimetres (3·3 inches); the tires to be properly welded, without flaws, and turned to a uniform diameter of three English feet. Every wheel to bear on the nave the name or mark of the maker.

ART. 3. The deliveries for each of the 7 contracts to be made in the following manner—viz.: Twenty wheels within 30 days following the acceptance of the tender by M. le Ministre, and 10 wheels per week afterwards, until the completion of each contract.

ART. 4. The letting to take place at Brussels, at the *Hôtel du Gouvernement Provincial*, at noon.

ART. 5. The tenders to be printed and drawn up to the annexed form, and must state precisely in full what discount per cent. the competitor offers on the price fixed for each wheel.

ART. 6. As the contracts will be let separately, a separate estimate must be sent in for each, notwithstanding the same person may be a competitor for several.

ART. 7. The tenders to state precisely the Christian and surname of the competitor and his sureties, with their signatures. They must be inscribed, " Tender of M. ——, for Contract for supplying the wrought-iron wagon wheels required in the execution of the railway works in course of formation."

ART. 8. Any tenders which are not of the above prescribed form and ad-

dress, together with any containing conditions different from those mentioned in the present specification, will be rejected.

Art. 9. Tenders which do not state a fixed per centage, and in precise terms, but contain merely an offer to supply the contract at a certain price less than that of the lowest estimate, will be rejected. Fractions are not to be used in the statements of discounts.

Art. 10. The prices on which competitors are required to name their discount are those stated in Article 1.

Art. 11. The cost of transport as far as the central magazine at Malines is to be included in the prices; the supplies must therefore be delivered free of carriage and every other expense whatever.

Art. 12. The supplying of the wheels constituting each contract must be completed at the periods fixed in Article 3.

Art. 13. A drawback of 100 francs will be made for each day's delay on the part of the contractors, in case of their not completing the supplies at the periods stated in Article 3, which will go to the treasury. The full right to this drawback to be recognised upon the certificate of payment being delivered in favour of the contractor for the contract executed.

Art. 14. Each package of wheels to be addressed to the "Garde Magazine at Malines," and to be accompanied with a duplicate invoice.

Art. 15. All the wheels supplied will be examined and proved within a month after their arrival at the depôt, by a committee of engineers appointed by the director of railways in course of construction. This committee will employ such means as it shall judge proper to satisfy themselves that the wheels are constructed of materials of the best quality, and fulfil the conditions of the present specification. The committee to have the power of prolonging the trials to 15 days before deciding, and to draw up a *procès-verbal* of its proceedings.

Art. 16. The contractors or their delegates may be present at the whole of the trials of the wheels which they have furnished. The decision of the committee shall be communicated to the contractors interested, by the director of railways in course of construction.

Art. 17. In case of the quality of the wheels being considered bad, and they are rejected, the contractor shall be bound to replace them by others conformable to the model in the course of one month from receiving the notice of it, and to remove those which have been rejected within eight days.

Art. 18. In case the contractors do not comply with the first of these obligations, the directors shall be at liberty to purchase the wheels requisite to

replace the former at any price, and at the expense of the contractors, notice of which will be given them. The contractors' supplies may be refused if they are not required, in consequence of the wheels being obtained elsewhere.

Art. 19. If at the time fixed in Article 3, the contractors have not completed the supplies composing each contract, they shall be provided by direct purchase at their expense.

Art. 20. In case of the wheels being supplied at the cost of the contractors, the extra sums paid above those stipulated in the contract will be deducted, as a matter of right, from the certificates of payment which will be delivered in their favour for the supplies sent in.

Art. 21. If the contractors have not sent in any supplies from the amount of which these costs can be deducted, they shall be bound to pay them within one month after being required to do so.

Art. 22. In case of the wheels being bought at the cost of the contractors, the drawback of 100 francs per day, as stipulated in Article 12, shall hold till the arrival of the goods (purchased) at the depôt.

Art. 23. The government reserves to itself the right of terminating the present contract by a simple notice by one of its officers to the contractor, in case he has sent in wheels of bad quality, or has not completed the supply at the periods fixed, the indemnity to be claimed in either case.

Art. 24. All disputes which may arise between the directors and the contractors respecting the execution of the contract, shall be submitted to the decision of *M. le Ministre of Public Works*, who shall decide finally. The contractors from that moment, and afterwards, to withhold all opposition to his decree by any mode of appeal or cessation.

Art. 25. The contractors shall present, for the acceptance of government, two personal and substantial securities, as a guarantee for the performance of their engagement, to be named in their tenders, and who shall sign the same with them.

Art. 26. The certificates of payment shall be delivered upon each supply of fifty wheels being decided to possess all the qualities required by the present specification. The payment to be made by bills, payable at sight, on the director of the treasury at Brussels.

Art. 27. The council will meet on the day and hour appointed, in the Hall of Adjudication, which will be opened to the public. The governor will take each of the packets in succession, from the box placed to receive the tenders of the

competitors, which being done, he will break the seals of each packet, and read, as they are opened, the discount at which each of the competitors engages to supply each of the contracts.

Art. 28. The Minister of Public Works reserves to himself the right of choosing from amongst the competitors who have submitted tenders, those to whom the contract will be given, and to accept them as such on a guarantee from their securities, without being obliged to make known his reasons for so doing. He shall have the right of refusing the tender which presents the greatest rate of discount, and of accepting another, offering less. He is not to be compelled to receive any, but may submit the contracts to tender again if he thinks proper.

Art. 29. The contractors state and declare that, as well for their own profit as for that of the government, the undertaking forming the object of the present contracts, shall remain altogether distinct and independent of every other undertaking which either now are, or may be hereafter, assigned to them; one of these undertakings being considered, as far as the duties and obligations resulting from it, and with respect to the other, as if they were contracted between different persons, so that any difficulties which may arise as to the execution of one of these undertakings, shall not, in any case, serve as a pretext to modify or delay another.

Art. 30. The cost of the stamp, printing, registering, and generally everything to which the present adjudication may give rise, shall be at the expense of the contractors.

Belgian Minutes of Specification for the supply of various articles required in the construction and maintenance of Railway plant, (material.) "*Extract.*"

Arts. 1 and 2 indicate the number of the goods to be supplied.

Art. 3. Each assortment of axle guards to consist of four axle guards, two connecting-rods, four coupling bolts, eight copper-plate counter clasps, four grease-boxes with brass bearings, eight spring straps, irons, and four covers for the grease-boxes with plate-iron hinges.

The guides to receive the grease-box, to be formed accurately, and smoothed with the file to the uniform thickness of 2 centimetres, (·787 of an inch.) The tenons and mortices to receive the connecting-rod are also to be shaped by the file, the two small keys to be cleft and pierced with a round hole; clasp irons, of the shape of a T, to be wrought out of a single piece, welded with a tenon, and carried without heat to the body of the axle guard. The axle guards and

their auxiliaries must be constructed according to the dimensions on the plan deposited at the Central, or Magazine at Malines, and equal to the model, which is also deposited there.

Art. 4. The rough axles of the carriages comprised in the 4th and 9th Contracts must be made in a single piece without welding, of strong nail-iron of the first quality. They must be constructed according to the forms and dimensions to be pointed out by the directors, their weight to be 100 kilogrammes (220lbs) per axle. They must resist, without fracture or splitting, the blows of a ram weighing 100 kilogrammes (220lbs), and falling from a height of 5 metres, (16 feet 4 inches.) Each time a delivery occurs, a tenth part of the number of axles to be examined will be subjected to this trial. If one of these axles composing the tenth breaks, the whole quantity under examination will be rejected; if one axle of this tenth splits, the trial will be renewed on a fresh tenth, (of the quantity delivered;) and if the same again happens—i. e., if one of these splits, the whole quantity under examination will be rejected.

The whole of the axles which shall have undergone the action of the ram, whether they have resisted properly or have been broken or split, shall in all cases be returned, to the loss of the contractors, and be considered as rejected.

Art. 5. The contractors will not be allowed to take away the rejected axles until they have fully completed their supply in reference to the present contract.

Art. 6. The administrator will remit to the contractor the old iron necessary for the manufacture of the axles to be supplied in virtue of the 9th Contract, 3 kilogrammes ($6\frac{1}{2}$lbs) of old iron being sufficient for the production of 3 kilogrammes ($6\frac{1}{2}$) of iron in the axles. The old tires of wheels to be considered as old iron, but not old rails.

The price of 22 francs for 100 kilogrammes (220lbs) to comprise all expenses relative to the re-manufacture. The conveyance of the old iron from the central magazine to the works of the contractor, and the return of the manufactured axles to be made at the risk and cost of the contractor, the administrator paying only for the loading of the old iron at the magazine.

Springs for the Goods Wagons.

Art. 7. The springs comprised in the 5th Contract must be constructed with the same care and accuracy as those deposited as models in the central magazine at Malines. They must comply with the following conditions respectively:—

Art. 8. Each set to consist of 4 springs of English steel of the best quality, which shall weigh together about 102 kilogrammes, (maximum 112, minimum 100 kilogrammes,) exclusive of the eight point-irons, which shall be made of strong iron of the very best quality, and be able to resist the blows of the hammer whilst cold.

Each spring to be 89 centimetres (2 feet 11 inches) long, when stretched *from centre to centre* of the eye-holes; to consist of 10 leaves, 78 millimetres (3 in.) wide, the first of which is to be 9 millimetres thick, and the others 6½ millimetres, ·354 and ·433 of an inch.) The leaves to be perfectly polished, tempered, and adjusted; they are to be fastened at their extremities by pins of 5 millimetres (·196 of an inch) in width. The ends of the leaves to be drawn out to a length of 10 centimetres (4 inches); they are to be riveted together by a bolt 11 millimetres (·433 of an inch) diameter, and a plate of 78 millimetres (3 inches) square to maintain the spring between the two straps of the grease-box.

The two upper leaves to have a curvature equal to 8 centimetres (3 inches), and to be terminated at the ends by eyelets, to receive round-headed nut bolts, 20 millimetres diameter (·787 of an inch) and 12 centimetres (5 inches) in length. Each point-iron to consist of—1st. Of an eyelet 35 centimetres (1 foot 2 inches) in length when spread out, 12 millimetres in thickness by 20 millimetres (·422 by ·787 of an inch) in width next the bolt, and 22 millimetres (·866 of an inch) diameter at the end. 2ndly. Of a gudgeon, with nut 20 centimetres (8 inches) long, the head of which is to be pierced with a hole to receive the eyelet, and to be 6½ centimetres (2½ inches) long by 5½ centimetres (2 inches) wide, and 2 centimetres (·787 of an inch) thick up to the extremity of the juncture, which is to be 3 centimetres (1 inch) long; the nut screw, as well as that of the bolt of the spring, to be 13 millimetres (·511 of an inch) thick, and to be squared with 3 centimetres (1 inch) each side.

Art. 9. All the springs to be proved by a screw press, and to bear a curvature of 10 centimetres (4 inches), without fracture or bending; they must not lose more than 1 centimetre (·39 of an inch) of their curvature on the first trial, nor exhibit any further alteration at a second one.

On a Composition of White Grease used with Wagons.

This mixture is not exactly the same on all railways. The first receipt which we have given is that adopted on the Versailles line (right bank), and

which forms a very good lubricating substance. This grease was formerly furnished at the price of 75 francs per 100 kilogs. by the engineer *Georges*.

	For Summer Use.	For Winter Use.
	kilogs.	kilogs.
Tallow (or fat)	50·00	40·50
Oil, called Oleine . . .	13·33	17·00
Salt of soda	3·34	2·00
Water	33·33	40·50
	100·00 = (220 lbs.)	100·00 = (220 lbs.)

The fat must be melted and poured into a barrel with some water, with which it is to be well mixed by a stirrer furnished with leaves. The oil and cold water to be afterwards added; then the salt of soda is to be dissolved in 10 kilogrammes of hot water, and the whole poured into the barrel, and turned until the grease of the proper consistency is obtained.

The following composition at present used upon the Orleans line gives equal satisfaction:—

	For Summer Use.	For Winter Use.
	kilogs.	kilogs.
White tallow	33·20	25·10
Whale oil	23·22	23·73
Salt of soda	2.08	2·44
Water	41·50	48·73
	100·00 = (220 lbs.)	100·00 = (220 lbs.)

Agreement of a Contract for the Execution of the Terminus of the Versailles Railway (left bank) at Paris, between the undersigned.

The Company of the Paris and Versailles Railway (left bank), through MM. Leo and De Bousquet, Directors of the said Company, agreeable to the authority given them by a resolution of the Board of Directors, dated 31st January, and 4th February, annexed to the present agreement, on one part; and M. Pierre Guillaume-Felix Colson, Building Contractor, residing at No. 31, Rue de la Ville-l'Evêque, Paris, on the other part.

It is hereby agreed as follows:—

Art. 1. M. Colson engages by these presents to construct, under contract for the Railway Company of the left bank, a terminus on the ground belonging to

the company, in the street, consisting of a ground-floor *entre-sole*, and a first-floor, and to execute the masonry and the terrace necessary for the masonry of a covered way, 50 metres (164 feet) in length, 18 metres 50 centimetres (60 feet 8 inches) in width, from axis to axis of the arched girders; and the Company have accepted the same, the whole conformable to the plans, descriptions, and contract (in duplicate) entered into between the parties whose signatures are to remain hereto annexed, perfectly united in the present agreement, the whole to be under the direction of M. Visconti, Architect, of Paris.

ART. 2. All the work to be executed with materials which are proved to be of the best quality, according to the rules of art, and also conformable to the orders of the architect, both as respects the nature and dimensions of the several articles to be supplied, and the mode of execution.

ART. 3. The contractor to bring forward for examination in seasonable time such articles which are inaccessible, or are not exposed to view after the completion of the work.

ART. 4. Such works as are badly executed, or performed with materials of inferior or second-rate quality, and not conformable to the orders given, may be disallowed, and shall be recommenced immediately, at the cost of the contractor.

ART. 5. In case of refusal to pull down and remove the rejected materials, it will be performed at the entire expense and risk of the contractor, the materials being deposited in the public road.

ART. 6. The contractor shall be bound to take all necessary precautions, at his own cost, to prevent the falling of earth; all accidents from this, and any other cause, will be entirely at his own expense.

ART. 7. The contractor shall be responsible for the effects of frost, as well as other accidents; he must consequently furnish and lay down planks, at his own expense, and other articles necessary for the preservation of the works under execution, of the mouldings, and arises, in order that the whole of the buildings may be surrendered in good condition at the completion of the works.

ART. 8. The contractor will not be entitled to any payment either for his own superintendence, or for that of his assistants, deputies, master associates, planners, or others.

ART. 9. The architect to have the superintendence of the work-shops. The contractor is consequently bound to defer to his orders on all points connected with the work, as well as the changing or dismissal of his foremen or workmen.

ART. 10. The whole of the works (of every kind) employed in raising the building, and rendering it fit for habitation, and furnishing it complete, are to be

made at the cost of the contractor, as forming part of the work agreed upon, and contracted for without any exception or reserve, including the filling up the chinks with chalk, the polishing and painting of planks, ladders, &c., and the removal of all the rubbish and scraps.

Art. 11. The amount of the contract hereinafter stated, cannot be altered, notwithstanding whatever size or depth the trenches may require to be made to secure a good foundation, or the nature of the foundation, stones, or piles required by the soil to make all firm, the nature of the ground, gravel, sand, or embankments, (always excepting the "*fonti de carrières*"—the works connected with which to be made at the expense of the company;) the conveyance under all its difficulties of landing or unloading materials, soil, or rubbish, and the removal of earth, the duration of the works, or finally any other cause whatever.

Art. 12. The contractor will not, in any case, be released from the responsibility imposed on him by the Articles 1792 and 1797 of the Civil Code.

Art. 13. The contractor engages expressly to fix all the iron work and other articles which the architect judges necessary for the solidity of the building. He is also to submit to any alterations in the partitions of the interior divisions, which the directors of the company may desire to introduce, provided always such requisition is made previously to the completion of the former, and that the alterations do not cause any increase in the expense, or injury to the contractor. Lastly, as an express condition of the present agreement, the contractor shall not be allowed any indemnity or increase to the sum hereinafter stated, for any errors or omissions which may have crept into the plans, contracts, &c.

Art. 14. No alteration is to be made in the particulars or deposited plans agreed upon between the parties without an express agreement in writing by the railway company. If any alteration be considered necessary, notwithstanding the preceding arrangement, the company reserves to itself the right of directing the omission of any of the works or portions of the works contemplated in the plans, of ordering alterations in the nature and forms of the materials of construction, and in the mode of execution and dimensions of the works at all times, and of further ordering additional works or portions of works.

Nevertheless, the alterations are never to be made, excepting in virtue of an express command, in writing, stating in formal terms, that it is made either in contradiction or in addition to the contract—consequently, every alteration in the contemplated works, or any additional works, not contemplated, which the contractor has executed or commenced, without obtaining an express order, shall, be considered as not constituting any exception to the contract. In order to pre-

vent any unexpected infraction of this stipulation, the contractor will not be allowed to appeal even to the written orders which he may have received from M. Visconti, the architect, respecting the execution of any alterations in the works without previous contract.

Art. 15. The company and the contractor shall determine amicably and by agreement, the amount of the omissions, alterations, and additions of the works which may be ordered in virtue of the preceding article. In case of a difference respecting the price or time to be allowed to the contractor for the execution of the additions or the omissions, it is to be fixed by M. Visconti, the architect, whose decision is to be binding on both the contractor and company, except the latter prefer to have the original contract executed in preference to making any alterations.

Art. 16. The contractor is bound to push forward with the building, so that the walls and works necessary to receive the iron roof shall be finished by the 31st March next, and the rest of the larger works by the 1st May following, and the whole of the works connected with the carpenters and joiners, smiths, ironmongers, painters, glaziers, or, in short, the entire completion of the same works, must be finished by the 15th June next. Therefore, if any portion of these works be not completed at the period above fixed, the contractor shall be liable to the fine now agreed to, of 100 francs for each day's delay. This indemnity, whatever it may be, shall be deducted in full right from the sum hereafter stipulated, however low it may be.

The company shall be entitled to this indemnity upon the mere fact of the above-stated time of completion being announced to have expired, without it being necessary for the company to demur at every delay, and which neither the tribunals nor the arbiters shall be able to modify, whatever be the state of the terminus at this period, and whatever the causes of delay of the works, the inclemency of the season being taken into account, and which is to be entirely at the risk and expense of the contractor.

As the time allowed for the execution of the works is very limited, the contractor will not be held responsible for the effects of damp in the painting and paper.

Art. 17. If the works be interrupted for fifteen consecutive days without a legitimate reason for the same on the part of the contractor, the Company shall possess the right of causing them to be continued by contract (made under the necessity), three days after a simple notice has been fruitlessly made, and at the cost, risk, and consequence of the contractor.

The Company shall have the right of using, under these circumstances, all the materials provided as a reserve by the contractor, who shall also pay the Company a fine, to be determined by the architect, and which shall be deducted in full right, from that which shall be due, without prejudice to the fine for delay contemplated in Article 16.

ART. 18. The amount of the contract is unalterably fixed at the sum of 108,688 francs (4347*l.* 10*s.*) for the entire completion and finishing of the building.

The removal of the earth to the level of the road to Maine, upon the site of the terminus, is not included in the above-stated sum, forming the amount of the contract for the terminus, and of the masonry of the covered way.

ART. 19. The Company will place at the disposal of the principal contractor a portion of the ground to the right of the terminus, on the road to Maine, for his stores, and he will also have the right of using the pit wells without any charge from the Company. The ground occupied must be surrendered up on or before the 15th May next.

Mode of Payment.

ART. 20. The payment on account of the above-stated contract to be as follows:—

Francs.	£.	s.	
25·000	(1000	0)	When the foundations of the terminus and the whole of the masonry of the covered way are on a level with the soil.
20·000	(800	0)	When the walls and other works are carried to their due height.
15·000	(600	0)	When the building is covered in, and the plastering finished inside and out.
15·000	(600	0)	When the joiners', and smiths', and ironmongers' works are finished, and fixed in their places.
13·000	(520	0)	When the painting and the other works of every kind are finished.
10·688	(437	10)	After the reception of the said works.
98·688	(3947	10)	
10·000	(400	0)	This sum, forming the balance of the contract for the works, is that alluded to in Article 19, the payment of which will take place one year after the completion and delivery of all the works, by means of and through the

delivery to be made to M. Colson of 20 shares of 500 francs in the Company for which M. Colson has subscribed, and which remain at present deposited in the hands of the Directors.

108·688 frs. (£4347 10) Total amount of contract.

M. Colson will not make payments for his shares by instalments, like ordinary shareholders, but will be free by means of this agreement upon surrender of the works to demand the immediate delivery of the said 20 shares, on his remitting into the hands of the Company the sum of 10 000 francs, in specie, in exchange for them, which will be forthwith converted into an "*inscription de rente*," at 3 per cent., in the name of the Company, which will remain in its hands until the 15th June, 1841; but M. Colson shall possess the right to demand that the said *inscription* be deposited with M. Halig, the notary of the Company.

Art. 21. All disputes which may arise during the course of the works, or after their completion, respecting the execution of the present agreement, as well as the examination and delivery of the works, shall be decided finally by M. Visconti, the architect, who shall be sole judge and friendly arbiter, and be able to act free of all judicial forms and delays. In case of the illness or death of M. Visconti, he shall be replaced by his assistant M. Delalande.

Executed in duplicate by the parties, as token of good faith.

Paris, 7th February, 1840.

Agreement of a Contract for the Execution of the Terminus of the Versailles Railway (left bank) at Versailles, between the undersigned:—

The Company of the Paris and Versailles Railway, (left bank) through their representatives, MM. de Bousquet and Bailey de Souy, Directors of the said Company, agreeable to authority given them by a resolution of the Board of Directors, dated on one part; and M. Ovacher Louis-Henry, Building Contractor, residing at Versailles, No. 2, Rue de la Paroisse, on the other. It is hereby agreed as follows:—

Art. 1. M. Ovacher engages, by these presents, to construct under contract on the grounds belonging to the company in the Champ des Mancennes, at Versailles, terminus consisting of waiting rooms, offices, marquee, porter's lodge, office for the commissioner of police, platforms, roofing iron, railing, and, generally, the whole

of the buildings laid down in the descriptive plan of the Company of the Railway from Paris to Versailles (left bank), who accept the same. The whole conformably to the plans and accompanying description, which are to be hereunto annexed, as an inseparable portion of the present agreement, and under the direction of M. Lepoitevin, architect at Versailles.

Art. 2. All the works to be executed with materials which are proved to be of the first quality, according to the rules of art, and also conformably to the orders of the architect, both as respects the nature and dimensions of the articles to be supplied and the mode of execution.

Art. 3. The contractor to bring forward in seasonable time the articles which are inaccessible, or not exposed to view, after the completion of the works.

Art. 4. Such works which are badly executed, or performed with materials of second-rate or inferior quality, and not conformably to the orders given, may be disallowed, and shall be recommenced immediately at the cost of the contractor.

Art. 5. In case of refusal to pull down or remove the rejected materials, the same shall be performed at the expense and risk of the contractor, and the materials deposited in the public road.

Art. 6. The contractor is found to take all necessary precautions at his own cost to prevent the falling of earth. All accidents from this and any other cause will be entirely at his own expense.

Art. 7. The contractor must furnish and lay down planks, at his own cost, and other articles for the preservation of the works under execution, of the mouldings and arises, in order that, at the completion of the works, the whole of the buildings may be surrendered in good condition.

Art. 8. The contractor will not be entitled to any payment, either for his own superintendence or for that of his assistants, deputies, master associates, planners, or others.

Art. 9. The architect to have the superintendence of the workshop: the contractor is consequently bound to defer to his orders on all points connected with the work, as also in the changing or dismissal of the foremen or workmen.

Art. 10. The whole of the works (of every kind) required in raising and finishing the building complete, without any exception or reserve, shall be at the cost of the contractor, as included in the sum agreed upon and under contract.

Art. 11. The amount of the contract hereafter fixed cannot be altered, notwithstanding whatever the carriage, and difficulty of the landing, or removal of materials, earth, or rubbish, may be the length of time during which the works may continue; or finally, any other cause whatever.

Art. 12. The contractor will not in any case be relieved from the responsibility imposed on him by the Act 1792 & 1797 of the Civil Code.

Art. 13. The contractor engages expressly to fix all the iron work and other articles which the architect judges necessary for the solidity of the building. He is also to submit to any alterations in the partitions in the interior divisions which the Company may wish to introduce, provided always such requisition is made before the completion of the former, and that the alterations do not cause any increase of expense, or injury to the contractor. Lastly, as an express condition of the present agreement, the contractor shall not be allowed any indemnity or increase to the price hereinafter stated for any errors or omissions which may have crept into the plans, contract, &c.

Art. 14. No alterations to be made in the particulars or deposited plans agreed upon between the parties, without an express agreement in writing by the Railway Company. If any alteration be considered necessary, notwithstanding the preceding arrangements, the Company reserves to itself the right of directing the omissions of any works, or portions of works, contemplated in the plan; of ordering alterations in the nature and form of the materials of construction, and in the mode of execution, and the dimensions of the works at all times; and further, of ordering additional works, or portions of works. But the alterations are never to be made, except in virtue of an express command in writing, stating, in formal terms, that it is made either in contradiction or in addition to the contract. In order to avoid any unexpected infringement of this stipulation, the contractor will not be allowed to appeal even to the written orders which he may have received from the architect respecting the execution of any alterations in the works, without previous contract.

Art. 15. The Company and the contractor shall determine, amicably, and by agreement, the amount of the omission, alterations, or additions to the works, which may be ordered in virtue of the preceding article. In case of a difference respecting the price or time to be allowed the contractor for the execution of the additions or omissions, it is to be determined by M. Lepoitevin, whose decision is to be binding on both the contractor and Company, except the latter prefer to have the original contract executed in preference to any alterations.

Art. 16. The contractor is bound to push forward with the building, so that all the works shall be finished, with the exception of the painting, by the 6th of August next. If these works be not finished by the period stated, the contractor shall be liable to a fine of 500 frs. for each day's delay; this fine, whatever its

amount may be, shall be deducted from the next instalment, from the stipulated sum hereafter mentioned, as a matter of right. The Company shall be entitled to this indemnity upon the mere fact of the above time of completion being announced to have expired, without it being necessary for the Company to demur at every delay, and which neither the Tribunals nor Arbiters' power shall be able to modify; whatever be the state of the station, and whatever be the causes of the delay of the works, the difficulty of the task being taken into the account, and being entirely at the cost of the contractor.

As the time allowed for the execution of the works is very limited, the contractor will not be held responsible for the effects of damp on the painting, which is done at the request of MM. the Directors.

Art. 17. If the works be interrupted during the space of eight consecutive days, without a legitimate reason for the same on the part of the contractor, the Company shall possess the right of causing them to be continued by contract (made under the necessity), three days after a simple notice has been fruitlessly and at the cost, risk, and consequences of the contractor.

The Company shall have the right of using, under these circumstances, all the materials provided by the contractor, as a reserve, who shall also pay to the Company a fine, to be determined by M. Lepoitevin, and which shall be discharged, as a matter of right, from that which shall be due to him, without prejudice to the fine for delay contemplated in Art. 16.

Art. 18. The amount of the contract is unalterably fixed at the sum of 61,000 frs. for the entire completion and finishing of the building out of hand. Nevertheless, it is formally stipulated that if the *façade* over the platforms costs the contractor more than 2700 frs., he shall be reimbursed the overplus, on the decision of a jury of examiners.

The said sum of 61,000 frs. shall be paid to M. Ovacher by the said Company—viz., 50,000 frs. on the delivery of the architect's reports, to be made every fortnight; the remaining 11,000 frs. will not be paid until three months after the final surrender of the works.

Art. 19. The Company will place at the disposal of the principal contractor a portion of the ground for his stores. The contractor must obtain a supply of water from wherever he can, and the Company is not to be bound to furnish the same.

Art. 20. All disputes which may arise during the course of the works, or after their completion, respecting the meaning or execution of the clauses of the

present agreement, as well as the examination and delivery of the works, shall be finally decided by M. Lepoitevin, the architect, who shall be sole judge and friendly arbitrator, and be able to act free of all judicial forms and delays. In case of illness or death of M. Lepoitevin, he shall be replaced by MM. Durand, of Paris, and Dorchin, of Versailles, architects.

Executed, in duplicate, by the parties, as token of good faith.

DESCRIPTION OF THE PLATES.

Plate 1.

First-Class Carriages.—London and Birmingham, and Birmingham and Gloucester Railways.

The first-class carriage of the London and Birmingham Railway consists of three compartments. The bodies rest on a double frame, supported on four steel springs *a a a a*, which are secured immovably by means of strap-irons, bolted to the grease-boxes *b b*, which receive the gudgeons of the wrought-iron axles. The wheels *d*, fixed upon this axle, are also formed of wrought iron, with the exception of the nave, which is cast. The iron guard-plates *c c*, serve to guide the grease-boxes in their movements, vertically.

The plan of the frame shows the upper part. There are four steel springs in the middle, two of which, *f f′*, are independent of each other, but are connected with the buffers *g g*, and serve to soften the violence of the shocks. The outer springs *h h′*, are secured together by iron rods *i i*, and form part of the drawing apparatus.

The Birmingham and Gloucester carriages consist of four bodies, two of them being in the form of a *coupé*, which are surmounted with imperials. The suspension springs are placed below the grease-boxes, which has the effect of lowering the carriages.

There are six spiral springs connected with the frame, which reduce the shocks from the buffers, and draw-links, instead of *bow-springs*, as may be seen by the plan.

Plate 2.

Carriages—London and Birmingham Railway.

A Second-Class Carriage:—This carriage does not differ from the carriage represented in the last plate, and employed on this railway. The buffing and

drawing apparatus are also similar, and the same letters of reference therefore will explain it.

A Third-Class Carriage:—This carriage is not enclosed like the last. The body is formed in one compartment, instead of being double, like the first and second class. The buffer-springs are omitted, and the buffers fixed. The drawing apparatus works like the former, by the springs h and h', which are connected together at their extremities, and receive the draw-rods across the middle. Their mode of action is such that one of the springs always returns the other to its original position.

Plate 3.

First-Class Carriages.—Great Western Railway.

The springs of both of these carriages are placed below the grease-boxes, in order to lower the centre of gravity of the carriages.

A Six-wheel Carriage:—There are two bow-springs only employed, consisting of steel leaves, and placed across the frame, which break the shocks: and two steel hoops, which are able to stretch out under the action of the motive force, serve for the drawing-rods.

A Four-wheel Carriage:—The ingenious arrangement of this mode of traction of this carriage deserves to be described in detail. It consists of two bow-springs, with the concave parts turned towards each other, and held by two cast-iron pieces $m\,m$. They are maintained by the rods $o\,l'$ and $l\,o'$, which form a fork, and embrace both at the same time. The position of these forks, and of the springs which they maintain, is secured by three guides. If we draw the two rods $o\,l'$ and $l\,o'$ in opposite directions, they press equally, and oppose the springs, extending across each other, without straining the former. If we push the rods instead of drawing them, the claws of the forks act upon the springs, which revert into an effort of exactly the same description as the preceding, but in an opposite direction.

The rods $o\,l'\,t$ and $o'\,s\,l$ guide the springs, and carry others, $n\,o$ and $n'\,o'$, which are fixed to the fenders $t\,t'$. These consist of planks fixed outside the frame, and form the sides of large triangles. They are fixed to the frame by bolts, of a description which admits of an oscillating and a turning movement about the points.

The fenders of all the carriages are attached together in a proper manner

when the train is moved, by which there are no jolts, notwithstanding the variations in the motion of the engine; and ether is therefore nothing to prevent the train taking a polygonal shape along the curves.

The Grand Saloon Carriage:—The interior of the body of this carriage is furnished with seats along each side, excepting at the openings serving for doors. The seats are formed in compartments forming stalls, which are capable of containing two or three persons.

Two tables are placed along the middle, formed with flaps, by which the passage may be left open if desired. The centre part of the roof is elevated, in order to allow of the passengers walking about in the carriage, without inconveniencing their heads against the ceiling.

The body is not rested immediately upon the frame, according to the plan followed with other wagons. There are eight air cushions between them in cachouca cases, and placed upon two longitudinal pieces, furnished with plate iron, and fixed to the frame by bolts. The cushions are maintained in their places by other iron plates fixed to the framing of the body, the edges of which are rounded. They are also held by bands fastened to the frame.

Plate 4.

Railway Carriages.

A Second-Class Carriage, Birmingham and Gloucester Railway:—This carriage is furnished with a break of the same construction as those applied to the first-rate carriages (formed with *coupés*) on this line, and represented in plate 1.

A Third-Class Carriage, Great Western Railway:—This carriage has six wheels. The same springs serve for both the buffing and the traction apparatus.

Details of a six-wheel carriage frame.

Plate 5.

Belgian Railway Carriages.

A First-Class Carriage:—The form of this carriage is unusual. It is divided into two parts, by a passage running transversely across the middle. Each compartment is furnished with seats, and accommodates nine passengers.

The horizontal steel springs *r*, shown in the plan, serve for both the purposes of traction and for breaking the shock.

A Second-Class Carriage:—The arrangement of the seats of this carriage is like the other.

A Third-Class Carriage:—The seats of this are placed across the wagon, and are six in number.

The details of these wagons very much resemble those of the Strasbourg and Bâsle, represented in plate 14.

Plate 6.

Railway Carriage Breaks—Versailles Railway (left bank).

No. 1. This break acts upon both sides of the wheels, and is exceedingly powerful, being furnished with four shoes—(i. e., upon one side).

It consists of a small balance beam A, supported by a vertical rod C, by means of a key B. The upper part of the rod is formed with a worm, in which a screw box works. There are two short rods on each side of the beam, each of which is furnished with a ring which receives the hooks terminating two levers E E. The latter are tied by means of pins F F to two iron patins G G, supporting the wooden shoes H H, which act upon the wheels. The levers carry two other small arms I I, which are attached to the extremities of the screw boxes K K, in which the screw rods L L pass, the latter consequently connect the shoes marked H H with those marked N N.

Upon turning the handle of the break, the balance beam rises and raises the two levers E E, which thereupon take an horizontal position, and press the shoes H H against the circumference of the wheels, at the same time drawing the shoes N N closer to the same. The wheels being thus checked upon both sides are effectually prevented from turning.

No. 2. The action of this break is a little different to the other, but it also operates upon both sides of two wheels.

Plate 7.

Carriages—St. Germains Railway.

A First-Class Carriage:—This consists of three compartments, two of which have imperials or seats on the roof. The two horizontal springs serve at the same time for easing the shocks and the purposes of traction.

The details will be found in the next plate.

A Third-Class Carriage:—This carriage is not furnished with horizontal springs, the buffers consequently are not elastic. The sides are merely enclosed with curtains.

Plate 8.

Details of Carriages—Versailles Railway (left bank).

These details principally illustrate the first-class carriage shown in the last plate, comprising the wheels, axles, buffer rods, and point plates, &c.

The drawing apparatus belongs to another carriage. When the links shown in the plan are jerked, the force is transmitted to the spring R, which acts at the same time upon another R′; the latter consequently acts upon the buffer placed between the two links. When, on the contrary, the buffer is compressed upon the plate A and the four guide rods S N, S′ N′ (two of which are shown in the plan), it slides the plate A upon the slide rods T T′, and the guides S N and S′ N′ enter the holes of the plate. The spring R′ is accordingly pressed by this action, which transmits the shock to the spring R, and the latter is supported by the fixed point P.

Plate 9.

First-Class Carriage—Versailles Railway (left bank)—Carriage with Coupé and Imperial.

Second-Class Carriage:—The details of this wagon are similar to those given in the next plate.

Plate 10.

Carriage—Versailles Railway (left bank).

A Mixed Class Carriage:—The middle compartment is intended to receive travellers of the first class, and the end ones those of the second class. Six passengers may be placed upon the seats of the imperial. The narrow divisions shown in the section serve to lodge dogs or baggage.

Plate 11.

Carriages on the Vienna and Brüun, and Strasbourg and Bâsle Railway.

An Eight-Wheel Carriage on the Brüun Railway (Nordbahn).

A Third-Class Carriage, Strasbourg and Bâsle Railway.

Plate 12.

First-Class Carriage—Versailles Railway (left bank).

No. 1. Carriage with three compartments.
No. 2. *Carriage de luxe*, ditto.

Plate 13.

First-Class Carriage—Versailles Railway (left bank).

Details of iron work, comprising suspension and traction springs, springs of the "*Carriage de luxe*," represented in last plate. The full lines in the details of the guard plate represent that of the ordinary first-class carriage shown in the same plate, and the dotted lines the guard plate of the "*Carriage de luxe.*"

A small step is shown by dotted lines in the figures of the grease boxes, which represents a small cast iron step, which is placed on the grease box as a point of attachment of the pin supporting the spring of the "*Carriage de luxe.*" The carriage upon which the gudgeon of the axle turns is formed of brass, but the remainder of the box is of cast iron.

The bolts and straps and some other pieces are employed in fixing the grease boxes to the suspension springs of the ordinary carriage. The "Frame Iron" unites the upper and lower longitudinal pieces of the frame, and guides the springs.

The plate shows the buffers and the draw rods. The extremity of the buffer spring lodges in the rectangular hole, lifts the latter, and the square part passes under the frame, and serves to guide the rod. The "Box Irons" which enclose the ends of the drawing springs serve as guides. The springs rest upon the lower iron, and the latter is placed upon the longitudinal piece, penetrating some millimetres into it; the Draw link, Safety chain and strap, the Screwing-up apparatus by which all the carriages in a train are united together.

Plate 14.

Details of Railway Carriages on the Strasbourg and Basle, and on the Versailles Railway (left bank).

These comprise the suspension springs of the carriages of the Strasbourg and Basle, and Versailles Railway, and mode of fastening the same; also the

traction rod, ring, and shield plate, cast iron piece supporting the buffer rods, end fastenings of traction and buffing springs, guides, and buffer rods, buffers, grease boxes, &c.; and the traction and buffing rods, buffers, &c.; traction rods, &c.

Plate 15.

Carriages: Mail Carriage—London and Birmingham Railway.

The frame of this carriage is similar to that represented in Plate 1 of the same railway.

A First-Class Carriage, Versailles Railway (right bank):—This frame is similar to that of the first-class shown in Plate 7. The details of the iron work are represented in Plate 8.

A Second-Class Carriage:—The frame is similar to the last example.

A Second-Class Carriage, Strasbourg and Basle Railway:—This frame is similar to those of the Belgian carriages, the details of which are given in Plate 14.

A mixed class carriage on the same railway.

Plate 16.

Details of Iron work, Railway Carriages.

These comprise the traction springs, &c., with the buffers and apparatus; buffer rods; draw rods; shield of traction rods; safety chain and straps; draw link employed on the London and Birmingham Railway. The drawing hook of this line is similar to that represented below the last figure, but the link is different. (*See draw link employed on the Southampton Railway.*)

The old buffers on the Orleans Railway were employed upon a body almost similar to that of the "*carriage de luxe*" in Plate 13, the springs being placed at each extremity. Old traction rods, Orleans Railway.

Plate 17.

Railway Carriage Wheels.

Wheels employed on the London and Birmingham Railway for earth wagons.—This wheel was cast in a shell *en coquille*. It is represented on a larger scale in Plate 47, "Third Series, Railway Practice."

Ditto, ditto, No. 2. This wheel is formed of wrought-iron, with cast-iron nave.

Ditto, Alais to Beaucaire:—A cast-iron wheel, with hollow spokes and wrought-iron tire, employed for goods wagons.

Ditto, ditto, No. 2, of cast-iron, formed in a shell.

Ditto, Orleans, &c.:—A wrought-iron wheel and cast nave. (This is the last pattern. It is also employed in England.)

Ditto, Strasbourg and Basle, ditto, ditto.

Ditto, London and Birmingham (Bramah's wheel) ditto, ditto.

Ditto, Belgium Railways. This wheel was in use formerly, and the whole, excepting the tire, was cast.

Plate 18.

Details of Axles of Railway Carriages.

Axle employed on earth wagons, London and Birmingham Railway:—The grease-boxes are placed within the wheels in this example, and the latter are 75 centimetres (2 feet 6 inches) in diameter.

Ditto, Versailles and St. Germain's Railway:—The grease-boxes are on the outside of the wheels, which are 50 centimetres (1 foot 8 inches) in diameter.

Ditto, London and Birmingham, No. 2:—The wheels of this, and of the whole of the following examples, are 0^m 90 to 1^m (3 feet to 3 feet 3 inches) in diameter.

Ditto, Strasbourg and Basle (old pattern):—This was used for passenger carriages.

Ditto, Versailles (left bank):—Used for all descriptions of carriages.

Ditto, Paris and Rouen:—For carriages.

Ditto, Versailles (right bank):—For all descriptions of carriages: weight mmes (212 lbs.)

Ditto, Paris and Orleans:—For all carriages.

Ditto, Strasbourg and Basle (new pattern):—For all carriages.

Ditto, ditto, (unfinished):—This represents the last model before it undergoes the cold forging.

Ditto, Hawthorne's six-wheel engine (with 12-inch cylinders).

Ditto, Sharpe and Roberts' ditto, ditto, (with 13-inch cylinders).

Plate 19.

Carriages—Rouen Railway.

A first-class carriage.
A second ditto, ditto, with break.
A third ditto, ditto (uncovered).

Plate 20.

Details of Carriages.—Paris and Rouen Railway.

These comprise the frame, with the springs, traction, and buffing rods, apparatus, &c. The traction operates upon the middle of the spring, by means of the rod shown in the figure. The shocks are transmitted by the buffers and rods to the extremities of the springs.

The suspension springs, with connecting rods, socket, grease-boxes, and point plates at the extremities of the springs, for securing them.

Plate 21.

Details of Carriages.—Great Western Railway.

These comprise the frame, traction and buffing springs, rods, suspension springs, guard-plate. The latter are distinguished from others by the small fillets which embrace the frame, grease-boxes of the first and second class carriages, &c. (see Plate 4).

Plate 22.

Carriages of St. Stephen's and Lyons Railway.

No. 1. The new eight-wheel carriage:—Carriages of this model were first run upon the line in September, 1842. They are capable of containing forty persons, without counting the outside places upon the imperial.

No. 2. Six-wheel carriage:—These were originally employed in the month of February, 1840.

No. 3. First-class carriage:—This carriage is placed at the head of the train, and is separated from the tender by a baggage-wagon, and another one uncovered,

in which there is a spare axle. This carriage weighs, with its load, 2250 kilogrammes ($2\frac{1}{8}$ tons).

The baggage-wagon is composed of a frame, the wheels of which are similar to those of the other wagons, and of a long body, formed in compartments, for the luggage. Upon arriving at the terminus, the body of this wagon is removed on to the limber of an ordinary carriage, and the luggage is thus transported to the offices of the Company, which are situated within the city, without being unpacked. A great loss of time is thus saved, while the property is likewise preserved. The weight of this wagon is 2690 kilogrammes ($2\frac{1}{2}$ tons).

No. 4. The old eight-wheel carriage:—These were placed upon the line in February, 1840, and accommodate 32 places, 8 of which are placed upon the outside of the roof.

Plate 23.

Details of Carriages.—St. Stephen's and Lyons Railway.

Plan, elevation, and longitudinal section of one of the two frames of an eight-wheel carriage:—

These frames are constructed perfectly independent of each other, and are explained by the references.

The hollow beams (Sablières), E E, are each formed of two pieces of wood, the outside piece is 0^m ·078 by 15^m (3 inches by 6 inches) square, and the others 0^m 15 by 0^m 04 (6 inches by $1\frac{1}{2}$ inches) only, and which is lined with plate-iron ·009 (·354 of an inch) in thickness. This arrangement is for the purpose of throwing the centre of the suspension springs further from the exterior, and sufficiently close to the extremities of the axles.

The beams are increased to ·015 (·59 of an inch) towards the middle of their length, so as to prevent their extremities from touching the under side of the carriages.

F F are wooden cross pieces, and employed to unite the hollow side beams, ·08 by ·14 (3 inches by $5\frac{1}{2}$ inches).

G is a piece of wood about ·07 by ·14 ($2\frac{3}{4}$ inches by $5\frac{1}{2}$ inches), upon which one of the pieces connected with the horizontal springs for breaking the shocks is fixed.

H, the principal wooden cross piece, which carries the main pivot. It is ·27 by ·165 ($10\frac{1}{2}$ inches by $6\frac{1}{2}$ inches), and is fastened in the side beams by

double tenons, and strengthened by an iron band bolted to the side pieces. Two strong iron plates cover the part crossed by the main pivot.

I I I I are iron rods ·015 (·59 of an inch) in diameter, which are intended to maintain the proper distance between the side pieces.

K is the main pivot, which is formed of wrought-iron, the cylindrical portion being ·055 (2 inches) diameter, the part embodied in the principal cross piece is ·065 (2½ inches) square. A certain number of circular iron plates are placed at the foot, ·009 (·354 of an inch) in thickness, upon which one of the pieces of wood forming the lower frame of the body of the carriage is placed.

L L are friction rollers, which prevent the side beams forming the body of the carriage bearing upon the side pieces of the frame, and consequently of opposing its rotatory movement.

There were friction rollers placed at each end of the side pieces of the frame, in the original carriages constructed upon this railway, and the body of the carriage rested directly upon them; but the difficulty in greasing rendered the motion difficult, and the frame required at the same time great power to move it; in consequence of which, this plan was suspended, and the body was supported upon plates placed round the main pivot, which arrangement has much improved the suspension, so that the shocks produced by the jolts are scarcely felt.

It is easy to understand its action: first, the shock produced upon one of the wheels being transmitted to the carriages by a single spring, is maintained by all four springs together, and its effect at the time is therefore reduced almost to nothing.

M M M M are the suspension-springs, which are ·78 (2 feet 7 inches) long and ·088 (3¼ inches) deep, taken in the middle. Each spring consists of twelve leaves, ·007 (·27 of an inch) in thickness and ·068 (2½ inches) wide; the middle of the springs rests on the grease boxes, which cover the gudgeons of the axles, and each of their extremities is secured by a kind of strap, (see " spring *straps* " in the plate,) which is fixed in the interior of the side pieces. The iron plates *e e* in the middle of the latter serve to guide the centre portions of the springs in their vertical movements. N (see plan) is a spring intended to soften the horizontal shocks. It is composed of five steel plates, each ·007 by ·06 (.27 by 2¼ inches), and maintained at *a* by a handle placed at the end of an iron bar, which is fixed at the lower part of the side pieces by two bolts; the other end of the spring passes into a bracket *b*, fixed to a piece of wood uniting the two cross pieces; this bracket is formed in such a manner as to grip the spring upon each

side, but at the middle of its height only; the latter is, consequently, compelled to move and play upon these two points of contact.

This spring was finished by a circular part, forming a pivot, in the first carriages, which method involved an operation that subjected the steel to injury, and also increased the expense; wherefore the former plan has been substituted, which effects the same purpose without subjecting the steel plates to any preparation; a hook, *d*, is also attached to the spring connected with the piece of wood, to which the buffers and traction-chains are fixed; the shocks resulting from the traction, and from the carriages knocking against each other, are thus broken. See longitudinal section of the extremity of upper frame, &c.

O O O O are the plate iron guard plates, of ·013 (·51 inch) in thickness, the two vertical edges of the opening, in which the grease-boxes of the axles are packed, are furnished with steel plates ·08 by ·015 (3 inches by ·59 inch), and are each secured by three rivets.

There is a moveable frame above that which we have described, which is also furnished with a spring; and, together with others already described, forms a system for breaking the horizontal shocks at each end of the carriages. This spring consists of six steel plates, ·006 by ·08 (0·23 by 3 inches), which are supported at the middle by a bracket *f*, to the first cross piece of the upper frame. There are two other brackets, one on each end of the spring, with rods connecting them to the buffing-piece *g*; these have the effect of turning the spring, or allowing of play at the point *f*, the effect of which breaks the shocks, which the buffing-piece *g* receives.

Plan and Sections of one of the three frames of a six-wheel carriage.

The three frames are perfectly unconnected, the same as in the carriages with eight wheels, and are formed in the following manner:—E E are hollow beams, formed of two pieces, and bolted together, and furnished with two strong plates of iron, each being ·064 by ·0135 (2½ inches by 0·53 inches), increased to ·015 (0·59 inch) in the middle of their length. The open space between them, in which the spring is placed, is ·10 (4 inches) wide.

F F F F are blocks uniting the two pieces of each side-piece.

G is the principal cross-piece, which consists of four pieces bolted together, and furnished with two strong iron plates ·24 by ·24 (9½ by 9½ inches), and ·013 (0·56 inch) at the centre, through which the main pivot passes. These plates are placed one above the other under the cross piece. H is the main pivot, which is like that of the former carriage.

I I I I, the bolts uniting the side pieces together.

K K, bolts for the purpose of joining the side pieces and the principal cross pieces together.

L, the spring to soften the horizontal shocks, and which is like the others.

M M, the small friction rollers.

N N, the suspension springs, each consisting of fourteen plates of ·007 (0·27 inch) in thickness, and ·068 ($2\frac{1}{2}$ inches) in width.

O O O O are straps to hold the ends of the springs.

The system described serving, as it does, for both the suspension and horizontal shocks, is both simple and strong; the experience of many years has demonstrated its superiority over others, more especially where the carriages are not united by stiff irons, the traction chains driving against each other, and the shocks to which they are subjected at the moment of the train starting, are violent.

The same system of buffer springs has been employed with much advantage for locomotives and tenders.

Plate 24.

Carriages.—Badois Railway.

The first-class carriage at the top of the plate is formed with three bodies, the centre one being formed larger than usual; one of the third-class carriages is without seats, but there are some rails fixed inside which the passengers can take hold of.

Plate 25.

Details of the Carriage Breaks.—Paris and Orleans and the Rouen Railways.

Fig. 1.

Elevation and Plan showing Levers, &c.

The handle of the break is elevated above the carriage, and is worked by the conductor of the train, when seated in his place. The vertical rod a (see Front Elevation of Lever) is turned by means of the handle b b, which raises the moveable screw box c in which it is screwed. The box c, having two small pivots in the checks d, operate upon the arm e e'. The fixed point f is held firm by the frame of the wagon. There is a horizontal rod joined on the square e' (the arms of which e e' are equal) which moves the large arm of the lever g fixed upon its axle. This communicates with two other smaller ones g' g'', each of which is

connected with a rod *h h* sufficiently strong to exercise a sufficient pressure upon the wooden shoes *i i*, which operate by friction upon the wheels.

The shoes are supported by two bolts upon a cast iron angular plate, *k*, which receives a tenon *l* in its middle, upon which the rod *h* is attached. The plate *k* also has another, *m*, attached outside of it, formed like a box, and which receives a thin plate bar *n n*, which is intended to maintain the distance between each pair of wheels correctly. There are small angular risings at the places where the plate bar is enclosed, which are fairly wrought, and a copper chair is placed on each, which is tightened at pleasure by the screws *o o*.

This plate bar *n n*, therefore carries and directs one of the extremities of the rods, the shoes, and the apparatus connected with them, and it further carries in its middle, in a circular hole, one of the ends of the axle *p*, upon which the levers are wedged. This axle maintains the distance between the two plate bars, of which only one is shown in the plate. We may readily perceive that this plate bar is carried at each extremity by the grease boxes, and secured by bolts *j j*.

The same apparatus is applied at the other side of the carriage, excepting such parts which are common to both, as the large rod and the lever. The break consequently acts upon the four wheels. The whole of the several parts of the break should be made with care, and be properly maintained and greased.

A A is the lower part of the longitudinal pieces of the wagon. We see by C that the long rod may be lengthened or shortened at pleasure by means of the screw box.

Fig. 2.

Elevation and Plan of Break employed on the Rouen Railway.

The rod *g* is that worked by the conductor (see Plate 19), and which is furnished with a handle *g′* when attached to passenger carriages, but in those for goods there is a wheel placed in the inside of the wagon instead, furnished with six pegs, which effect, by means of two conical-toothed wheels, the movement of the vertical rod (see Plate 34). This rod carries a pinion at its lower extremity, which works a wheel of double its diameter, and thus transmits the motion of the levers to the rods &c., as in the preceding instance.

The small roller *r* presses upon the rack, and forces it against the larger pinion.

The cogged wheels are placed in a box which is open upon each side to receive the extremities of the axles of the same.

The iron work of the shoes *s s* is like the former, but formed with much

less care and precision, such room being left for play that it is useless greasing the parts. The shoe *s* is attached to an angular piece *t t*, upon which another piece *n n* is attached, which embraces a long flat bar, and thus maintains the distance between the wheels. It is supported on the grease boxes as the former, but the bolt of attachment *v*, is vertical.

Plate 26.

Railway Carriages.—Springs Employed in England, France, and Germany.

Spring of First-Class Carriage, Rouen Railway :—This spring being horizontal, the jolts are not much felt. It consists of a copper band ·018 (·70 inch) in thickness, and ·08 (3 inches) wide, and of nine leaves, ·008 (·31 inch) in thickness.

Ditto, Goods Wagon :—This consists of five leaves, each ·009 (0·35 inch) in thickness, and separated by metallic plates.

Spring of First-Class Carriage, Liege Railway :—This consists of eight leaves, each of ·008 (·31 inch) in thickness; the extremities of the spring are joined to the straps by two rings.

Ditto, of a Second-Class, Manchester and Leeds :—The two leaves of this are ·01 (·39 inch) thick, and separated by small wooden blocks.

Ditto, employed in Germany.

Ditto, upon the Manchester and Sheffield.

Ditto, of a Second-Class, Great Western.

Ditto, employed in Germany (No. 2). This is employed for passenger carriages. The extremities are connected with a balance, *a*, *b*, which turns upon the point *o*, and thus facilitates the passage at the curves, by approaching a certain distance towards the axles, and enabling them to take the direction of the radii to the curves.

Ditto, of a Second-Class, Great Western, No. 2.

Ditto, of a Goods Wagon, Rouen and Havre.

Ditto, for a Second-Class (No. 2). This has been used in England. The spring was ·12 (4 inches) long, and ·02 (0·78 inch) thick in the middle, and ·01 (0·39 inch) at the extremities.

Ditto, of a Goods Wagon (No. 2) :—The lower leaf is ·016 (·62 inch) in thickness, and the upper ·01 (·39 inch), and they are long ·07 (2·7 inches), separated by a wooden block, ·027 (1 inch) thick.

Ditto, of a Mail Carriage, South-Eastern Railway :—The spring is combined with a band of copper at the upper part.

Ditto, of a Goods Wagon, Leeds.

Ditto, upon the South-Eastern Railway:—This plan is also employed with a copper band above it, like the first example.

Plate 27.

Carriages.—Orleans Railway.

A goods wagon.

This wagon consists of an enclosure which is furnished with two doors marked A A, in the elevation. The mails or baggage are placed therein, upon a raised floor. There are two closets under the latter, *c c c c*, which serve to keep the passengers' dogs, which are booked and paid for. The interior is also furnished with shelves, *a a*, supported on brackets, upon which the carriers dispose the different parcels; the lockers, *b b*, also hold various goods.

The mode of suspending this wagon does not differ from that of passenger carriages, and the system of traction consists of a simple hook.

A Mixed Carriage:—This wagon is employed on the St. Germains Railway, and principally for baggage.

Plate 28.

Details of Railway Carriages.

Mr. Arnoux' Carriage, Orleans Railway:—This is employed to transport the bodies of diligences on this line.

Goods' Carriage, Strasbourg and Bâsle Railway.

Carriage-truck, London and Birmingham Railway.

Railway Carriage Shifting Truck, Versailles (left bank):—This is employed at the depôt to transport carriages from one line to another.

Goods' Truck, Strasbourg and Basle Railway:—There are pins placed in the socket-holes at a a' a'' when required.

Plate 29.

Railway Wagons.

Coal Wagon, Strasbourg and Basle Railway.

Goods Wagon of ditto.

Coal Wagon, Alais and Beaucaire Railway.

Wagon, London and Birmingham Railway.

Plate 30.

Details of Goods Wagons, Strasbourg and Basle Railway.

An Eight-wheel Wagon:—This wagon consists of a very large frame, 10 metres (32 feet 10 inches) long, which rests upon four conical friction-rollers supported on two small carriage frames.

These are perfectly separate, and are each fixed on two pairs of wheels. The two carriages are kept in their proper positions by two pivots, which fit into sockets placed beneath the long frame, and by chains at each corner.

A four-wheel wagon.

Plate 31.

Details of Eight-wheel Wagons.—Strasbourg and Basle Railway.

These details consist of the frames supporting the carriages and tie-rod between the wheels of same; stirrups for horizontal end springs; stirrups for vertical springs.

The upper, or socket-plate—the two arms *a* and *b* in this plan—lie in the direction of the longitudinal axis; the lower, or pivot-plate, cap plate, which serves as the point of attachment of the side stay-rods, iron in centre of upper carriage-frame, which is shown in the elevation, (see last Plate.)

Friction-rollers at A A′ on large plan. There are two rollers to each carriage, which support the weight of the body. The pivots may be allowed to carry a small portion of it, but they must not be overloaded. The end shield for the traction-rod—the traction-rod passes through the large orifice—shown in the plate, and the other holes receive the bolts.

Plate 32.

Details of Four-wheel Wagons.—Strasbourg and Basle Railway.

These comprise the timber work, as the centre cross piece, which receives the diagonals; the diagonal pieces and straps to the same; end of wagon; end cross pieces, showing their connexion with the side pieces; centre longitudinal piece; upper centre cross piece; one of the upper cross pieces, and the side pieces which receive the guard-plates.

Plate 33.

Details of Railway Carriages.

These comprise the grease boxes of the goods' wagons employed on the Strasbourg and Basle railway. They are composed of two parts, *a* and *b*, (see the Figures,) which are separated a little in the " Side section" and " Front," to show the mode of construction better. A groove is shown in the former within the circular edging to receive the side disc, by which the grease boxes attached to each wheel are protected from the sand. The discs are formed of plate iron, and are secured to the naves of the wheels by four screws, as shown in the " Elevation of Wheel." The cover is placed over the box, and secured between two spring plates.

Guard plate of the same wagon. Buffer rods of M. Arnoux's carriage truck, (see Plate 28) with the prolongation to the extremities. The rod A is situated between the left rectangle, and presses the end of the traction spring.

Plan and Section of Frame of M. Arnoux's carriage, with details of the forked piece *a*:—These forks support the weight of the carriage, and are placed parallel at each extremity of the wrought-iron diagonal pieces. The carriage also rests by the springs upon four pivots. (See the Plates showing M. Arnoux's wagon and his travelling crab.)

Tie rods to guard plates of the goods wagons, Strasbourg and Basle:—The extremities of the guard plates *c c*, pass into the mortices *c′ c′* in the plan, and the small bolt shown by the side unites them.

Wheels of the same wagon:—Upper and lower plates placed in the middle of the horizontal traction springs.

Guides and Plates:—No. 1. Being the wedge which unites the upper guide with the buffing-rod. No. 2. Guide at the extremities of the traction springs. No. 3. Guide at the extremities of the suspension springs. No. 4. Exterior guide of the traction rods: this piece is shown in the end view of this wagon. No. 5. Plate in the middle of the traction springs, at the side opposed to the curve. No. 6. Ditto, counter plate placed next the springs or the rod. These two plates being united by four bolts (the holes of which are shown) embrace the middle of the spring which lays in the hollow parts *d d*, and the side-plates represented below them, run in the parts *e e e e*.

Elevation and Plan of traction springs; ditto, of suspension ditto; both of the same wagon; stirrups to same; screw links, which are hung on the drawing-hooks shown by the side; the stirrup which receives the middle of the traction spring is fixed at the other end of this rod; safety chains and hooks.

Plate 34.

Wagons.—Paris and Rouen Railway.

Baggage Wagon:—The passengers' trunks and other luggage is packed in this wagon. A conductor is shut within it, who takes his place upon the platform *a*, which is furnished with the seat *b;* he is sufficiently elevated to allow of his head being above the wagon, and he engages himself in looking out through the windows *c*, which are glazed all round, by which he can command the entire train, and also take the signal from the engineer. One of the squares of glass, parallel with the line opens; for instance, that shown at *d*, in the side elevation, which figure describes the mode of operation of the break. There is a small wheel, furnished with six handles, which the conductor turns in the direction of the bends, to press the break, as shown in this plate, and which is more particularly described in Plate 25.

The dotted lines on each side show the size of the body, and the range of the doors, which open outwards. This description of door (opening outwards) is dangerous, and no doubt caused the accident in the month of January, 1844, on the Orleans Railway, since which period they have all been replaced by sliding doors.

The horizontal springs are six in number, which appear extravagant. The two small springs serve for the traction, and the other four for neutralizing the shocks. There is a reason for this wagon having such a number of springs; it is generally placed at the tail of the goods train, the wagons of which have neither springs nor buffers (see the goods wagons in this Plate). The shocks, which are consequently very violent, are transmitted to this wagon, which therefore requires to be made capable of resisting them. We see that the large springs *a a* are connected in the centre part, and move together by the assistance of the iron slides *e e*, shown in the plan.

Goods Wagons:—All the goods wagons are suspended and furnished with breaks similar to this. The end of the lever handle is supported in the guide *f*, and a notch is shown (see End Elevation) which receives the handle when the break is not acting.

Wagon for carrying milk:—This wagon is suspended, but is not furnished with traction springs, nor any more than stuffed leather buffers. There are four doors and two floors, *g g* and *h h*, as shown upon the plate. The lower one is boarded all over, and as many pails as possible are placed upon it. The upper one consists of rails, and is also covered like the other. The entire load

does not rise above the upper edge of the wagon. The wagon contains about 192 pails, or 96 on each floor. If each pail equal one decalitre, the weight would equal 1920 litres, or near two tons, exclusive of the weight of the vessels.

Plate 35.

Details of Goods Wagons.—London and Birmingham Railway.

These comprise the suspension springs and guard plates; plans, elevation, and section of the grease boxes; ring plate for safety chain; drawing chain; traction rod and hook; stirrups to springs by which the latter are secured to the grease boxes; cast iron point irons for springs, which are fixed to the longitudinal pieces, and hold each extremity of the springs.

The break plate, which is fixed to one of the longitudinal pieces of the frames, and serves to sustain the axle of the break; hook for sustaining the break; guard iron for the wooden shoe of break; plan of frame; longitudinal sections through the body of the wagon, &c.

Plate 36.

Details of Railway Horse Boxes.

Wagon employed on the Versailles (left bank), for Horses and Small Parcels:—The stalls for each horse *a a a* are formed by moveable partitions, the part *b* is intended for baggage, and the conductor and passengers take their places above. Each side of the wagon (longitudinally) is composed of two parts or shutters, with horizontal hinges, one lifts up, and the other falls down upon the platform, forming a drawbridge for receiving and landing the horses. This will be readily understood by reference to the transverse section of the wagon below, in which one side is shown with the flaps open.

Six Horse Box, Versailles Railway (right bank):—The body of this wagon is formed in two compartments, each divided into three stalls, the divisions are fixed, but there are openings for the convenience of taking the horses in and out. There are leather bands *b b* stretched across the stalls, at the breasts and haunches of the horses, to prevent their injuring themselves against the partitions, at the stopping or starting of the train.

Orleans Railway:—This is a box for three horses, the doors of which are situated at the ends.

London and Birmingham Railway:—This is also a wagon for three horses;

the walls are hung upon hinges, and the partitions are moveable, and slide in vertical grooves at each end of the box.

Strasbourg and Basle Railway:—Each of the boxes accommodates a horse; they are placed on small wheels to facilitate their movement, and a number sufficient to accommodate the horses required to be removed are run upon the platform.

Plate 37.

Details of Goods Wagons and Break Carriage.

The goods wagon, London and Birmingham Railway, has been recently made. The internal lining is not shown in the transverse section of the other goods wagon, in order that the arrangements of the framing may be seen.

Break Carriage employed on the Liege Inclined Plane.

This carriage is generally placed at the head of the train when it ascends and descends the incline. In the first case the clutches *l l*, which are connected with it, seize the rope, and in the latter the carriage is left to itself.

The break adapted to this wagon acts directly upon the rails instead of upon the wheels. It is composed of a wooden shoe, $1{\cdot}20^{m}$ (4 feet) long, by 0·12 (5 inches) wide, and 0·27 (11 inches) deep, and furnished below with a strong piece of iron of an inverse shape to the rail, in order to embrace the whole of its surface, and thus increase the adhesion.

There is a vertical axle in the middle of the wagon which is furnished with a handle *m*, at one extremity, and terminated at the other by a screw engaged within a moveable screw box, which allows of the shoe being moved in a vertical plane by means of levers *t′ t′*, and rods *t t*.

The pressure is applied gradually upon the rails, and when it attains a maximum, the wheels are raised, and the weight of the carriage, which is about 8000 kilogrammes (7 tons 1 cwt. 3 qrs.), is lifted completely above the rails.

This wagon is sometimes preceded by a sledge, which slides upon the rails by means of two iron patins. The resistance of this sledge causes an addition to that of the wagon, and consequently diminishes the velocity of the train. The bell shown in the elevation is employed to announce the departure and arrival of the train.

The side elevation and transverse section show the arrangement of the breaks, and the levers employed in moving the same.

Details of Clutch Apparatus:-

In the "view of clutch" *a a* is a sort of jaw in which the brass chair *a′ a′* is placed. In the "return view" *d* is the lever employed to move the clutch *l*, which moves upon the axis *g*. The lever pinion *r* catches in the cast-iron circular rack *k*, and seizes the rope in the jaw *a*. When the lever *d* is raised, the latter is fixed by the catch *s*.

The position of the levers when the clutch operates, is represented by *d′ l′ r′ s′*, and when the clutch leaves go of the rope at the bottom of the incline, by *l″ l″*.

Plate 38.

Turn plates and Fender Stops, Versailles Railway, (right and left banks.)

The Fender-Stop (*Heurtoirs*), on the Versailles Railway (left bank), is placed at the extremity of the line.

P P, are walls formed of masonry which support the turnplates, platform, &c.

O O O, Stone Piers.

M M, Retaining walls sustaining the embankment forming the railway.

N N, Retaining walls forming a portion of the foundation of the waiting hall.

Plate 39.

Details of Hydraulic Cranes on the Versailles (left bank), the St. Germains, and the London and Southampton Railways.

Hydraulic Crane upon the Versailles Railway:—This crane is exceedingly simple. It consists of a hollow cast-iron column A, supporting a dome B, which is surmounted by a gas lamp F. A cast-iron pipe, C, is fixed inside the column as shown in the enlarged section of the head, &c., into which the end of a pipe is fitted by means of the stuffing box E, which is furnished with a flexible hose.

The tanks which supply water to the cranes, are placed at a certain height above, and communicate by conduits with the internal pipe C, a cock being placed near the crane to regulate the same.

Hydraulic Crane on the St. Germains Railway:—This crane, like the last, consists of a cast iron column, but terminated below by a cross foot-plate which is let into solid masonry, which supports the casing. A cistern B, is placed at the upper

part, in the bottom of which there is a valve, and an upright rod connected with it, rising above the covering of the cistern.

A horizontal beam is attached to the rod with a counter-weight fixed at one end, and an iron chain at the other, by means of which the men are enabled to raise the valve, and draw water from the tank, and to pass it by the pipe G, into the top of the tenders. This pipe is supported by an ornamental cast-iron bracket J, turning in a socket below K, and encompassed above by a brass collar M, secured to the side of the column.

The supply pipe P, is furnished with a cock O, which cuts off the communication with the tank, and enables the workmen to perform any repairs that may be required without being inconvenienced by the water in the tank.

The other crane is like the former, and will be readily understood by an inspection of the plate.

Plate 40.

London and Birmingham Railway.—Details of Hydraulic Cranes.

This crane is more complicated in its construction than those in the last plate.

The water is raised in a cast-iron column A, sustained by three strong stays L, which are disposed in the shape of a triangle. By means of a valve enclosed in a square cistern B, a communication can be opened and closed at pleasure between the column A, and the branch G. The latter turns upon the pivot K, and the stuffing-box D.

Plate 41.

Paris and Orleans Railway.—Details of Hydraulic Cranes.

This crane is composed of a vertical cast-iron column A, which is partially fluted, and furnished below by a large foot which forms the foundation plate, and is tied to the body of the crane by four supporting brackets. The upper part is terminated by a cylinder which enters with trifling friction through a stuffing-box, and is surmounted by a sphere. The latter is adapted so as to support a lever which serves to open and close the valve situated at the lower part of the moveable cylinder, as indicated in the enlarged section of the head.

This sphere is level with the horizontal branch G, by which the water is passed into the tenders. The branch is supported by a console, and the lower part is bolted to a collar K, which embraces the column A, and which is enabled to turn in the neck formed by the fillets round the column.

In order to intercept the communication between the tank and the crane, whenever necessary, the supply pipe P, carries a rectangular cast-iron box M, enclosing a cock. This is worked by means of a long rod and handle carried upwards through a small cast iron column, over the box M, and elevated above the ground.

Plate 42.

Strasbourg and Basle Railway.—Details of Hydraulic Cranes.

The large cock shown in the details furnishes the supply, and establishes or closes the communication with the tank, and the small cock is employed for emptying the crane.

Plate 43.

London and Birmingham and Newcastle and Carlisle Railway.—Details of Hydraulic Cranes.

Hydraulic Crane, London and Birmingham Railway. The bolt A—B, shown in the section, connects the two iron arcs together, and is intended to prevent the upper part of the crane being separated from the lower by any violent blow.

The engineer works the valve D, from the tender by the help of a handle E.

The hollow sphere F, acts as a counterpoise.

Hydraulic Crane, Newcastle and Carlisle Railway:—The valve, in this instance is placed at the bottom of the vertical pipe.

Plate 44.

Details of the Southampton and the Nordbahn and Vienna Stations.

References to the General Plan of the Station of the London and Southampton Railway:—

A and B. Building of two stories for the workshops.

A. Steam engine.

B. Workshops.

C. Forges.

D. Small depôt for iron, &c.

E. Wagon shed.

F. Omnibus court.

H. Vestibule.

I. Office for the distribution of tickets.

K. Entrance hall.

L. Office.

M. Court for the use of goods. The principal way communicates with this court by an accommodation line, which is not shown on the plan.

References to the General Plan of the Station of the Nordbahn and Vienna Railway :—

A A A. Waiting rooms.

B. Vestibule.

The waiting rooms and the vestibule are at the level of the railway, which is formed 4^{m} 50 (14 feet 9 inches) above the natural level of the ground.

The principal staircase conducts to the vestibule and to the waiting rooms of the first and second class, placed on the left. An additional staircase conducts to those of the third class, placed on the right.

C and D. Porter, work people, inspector of police, office for the issuing of tickets, &c., &c.

The second floor which is arranged like the first, has not yet been appropriated to any purpose.

E. Shed for forty wagons, with vaults serving for the stores. The clock is in the roof of this building.

F. Workshop for repairing the wagons.

H. Ditto, ditto, engines.

I. Shed for twelve engines, with pits beneath the ways. It encloses two cranes.

K. Coke depôt and reservoir, with pit for collecting the coke and receiving the water which fall from the locomotives. Four engines can stand upon the length of way placed in this building. The water of the reservoir is heated with the waste coke before being turned into the tender. The coke stores contain about 4800 standard quintals ($472\frac{1}{2}$ tons) of fuel. This is the only building at the station which is covered with tiles, the others being roofed with plate iron.

L and M. Accommodation ways.

N and O. Ways for goods.

P. Arrival line.

Q. Departure line.

R. Magazine on the level of the way, and at the first stage of this building.

S. Collectors.

The great halls to the second story and to the level ground serve also for storehouses.

Plate 45.

Details of the Nordbahn and Brün Railway Station.

References to the General Plan of Brün station:—

A B C D E F G. Building forming the entrance halls of two stories.

A. Vestibule.

B C D and E. Entrance halls.

F and G. Ticket offices, &c.

H and I. Warehouses for depositing the goods.

K L and O. Service ways to the sheds.

M. Departure line.

N. Arrival line.

P. Shed for eleven engines.

Q. Ditto wagons.

R. Workshops for repairing engines.

S. Ditto wagons.

T. Building containing reservoirs for water.

Plate 46.

Details of the Versailles Railway (right bank) Station at Versailles, and the Pecq Station on the St Germains.

Reference to the General Plan of the Versailles Station:—

a a. Court of the form indicated in the plan, and enclosed from the Rue du Plessis by an iron railing. Three gates are placed in this railing, the middle one being of large dimensions, and the others, at the sides opposite the footways, are smaller. The latter are only made use of on fête days, and for pedestrians.

An asphalte footpath of 5 metres (16 feet 5 inches) wide surrounds this court.

b b b. Great vestibule.

c^1 and c^2. Direction office for travellers.

c^3 and c^4. Ditto ,luggage.

The travellers, after having taken their tickets, ascend the staircase shown between the offices, c^1 c^2, to the waiting-room *e e*, which they reach by following the staircase.

$f f^1$. Apartments of the station master, superintendent of police, &c.

e e. Waiting-room, having doors *from one* platform to the other, *d* and d^1.

The passengers of the different waiting-rooms are only separated from one another by balustrades.

d and d^1. Covered platforms, as shown in the section, which serve alternately for the departure and arrival.

g and g^1. Ways serving alternately for the departure and the arrival.

h and h^1. Service ways for locomotives, with pits for cleansing them.

k and k^1. Ways leading to the sheds.

Each way is terminated by a turn-plate.

l l. Reservoirs for feeding the hydraulic cranes, placed near the pits.

m m. Garden.

q and q^2. Sheds.

p p^1 and p^2. Changes of way.

References to the General Plan of the Station of Pecq:—

a a a. Quay opposite the wharf.

b b. Vestibule.

b b^1. Ticket offices.

Wooden barriers are shown before these offices in the vestibule, which serve to direct the crowd.

b^2. Luggage office, having a communication with the vestibule; another with the quay; and a third with the station.

b^3. Office for directing parcels.

c. Passage to the platforms of the station.

d d. Exit staircases.

b^4. Exit vestibule.

e e. Waiting rooms, in which travellers of different classes are only separated by barriers. These waiting rooms are edged by wooden platforms, which separate them from the ways *g g*. (See the Section.)

g g g and $g' g' g'$. Ways serving alternately for the arrival and departure of the trains.

h h h. Ways for the use of engines.

Each of the ways *g* g' and *h* is terminated by a turn-plate and a fender-stop.

The platforms and the ways *g* and g' only are covered, as shown in section.

b^5. Office of the superintendent of police.

b^6. Guard-house.

b^7 b^8 b^9. Direction offices for travellers by the carriages for the corresponding department, with the necessary appendages in this service.

b^{10}. Office of the station master.

i and *k*. Court where the omnibuses stand which convey travellers to and from the station.

n n. Lateral ways to the shedding.

The travellers, after having taken their tickets at the offices b', pass into the waiting-room, following the passages formed by the wooden barriers figured in the plan. Entering upon the platform *c*, they can pass into either of the waiting-rooms. Only one of these rooms is required on week-days, for the departure, when the trains always start from the furthest line. Travellers arriving, cross the room *e*, and go out by the staircases *o*, from whence they depart by the staircases *d*, passing through the room b^4. On Sundays and fête days the trains set out alternately from the ways *g* and from g', arriving sometimes upon one and sometimes upon the other of these lines. The waiting-rooms *e* and e' serve also alternately for the departure.

Travellers of different classes are only separated in the waiting-rooms by simple wooden balustrades.

Plate 47.

Paris and Versailles Railway (left bank.)—Details of the Stations at Paris and Versailles.

References to the General Plan of the Station at Paris:—

A. Buildings forming the waiting rooms.
B. Entrance gate of the omnibus court.
D. Omnibus court.
G. Private room of the station master.
L. Carriage shed.
N. Workshops for repairing locomotives and carriages.
O. Closets for the workmen.
J. Garden behind the shed.
P. Circular shed, where engines are cleaned and repaired.
Q. Vats filled with water.
R. Porter's lodge.
R′. Door for the entry and departure of workmen.
S. Store house.
T. Coke house.

U. Quay for loading carriages.

V. Depôt for coke and sundries.

X. Large open space, serving for timber, upon which a forge is built for reheating the tires of the wheels and for binding them on. The dotted lines show the fencing.

a, a^1, a^2. Plan at the level of waiting rooms.

a. Second-class waiting room, having a view of the road to Maine.

a^1. First-class ditto, having a view of the railway.

a^2. Waiting room for travellers at the stations.

a^3. Staircase and landing place, by which travellers pass into the waiting rooms.

a^4. Landing place by which travellers leave in passing from the waiting rooms to the platform.

a^5. Closets for travellers.

a^6. Grand staircase for the exit.

a^7. Portion of the platform covered by a roof, as shown on elevation, upon which travellers of the first class can promenade until the departure of the train.

b. Staircase conducting to the court of a house adjoining the station.

b^1. Staircase by which the officers of the company communicate with the station.

c. Departure platform.

c^1. Arrival platform.

These platforms are formed of planks. They are supported, as shown in the elevation.

d. Departure line.

d^1. Arrival line.

The travellers from Paris sometimes go by the platform c^1 on fête days, to avoid changing the carriages on the way, upon which they also arrive from Versailles. The train passes by means of the crossing place x^1 on the departure line.

d^2. Accommodation way for engines.

d^3. Way to shedding.

d^4. Way communicating with the carriage sheds.

d^5. Curved way of 125 metres (137 yards) radius, for the use of the engine sheds.

d^6. Curved way for the use of engine sheds and for changing carriages or certain goods.

d^7. Way for the shifting truck, which is built after the plan shown in Plate 28.

e. Fender stop.

$f f^1 f^2$. Turn-plates:—These are upon the old plan.

$f^3 f^4$. Turn-plate for establishing the communication between the carriage shed and the departure line. The plate f^3 is upon the same system as the 21-feet turn-table, shown in Plate 27, "Third Series of Railway Practice."

$h\ h^1\ h^2$. Pits for cleaning the locomotives, etc.; they are enclosed with fencing, to prevent accidents.

$i^1\ i^2$. Hydraulic cranes, upon the model represented in Plate 39. These communicate with reservoirs or vats Q, by cast-iron subterranean conduits.

i^3. Small apparatus for washing carriages.

j j. Rack upon which sacks of coke are placed for loading the tender.

k. Change of way for passing engines from the accommodation way to the departure, or *vice versa*.

$k^1\ k^2$. Change of way for conducting the train from the arrival line to the departure.

k^3. Change of way for communicating with the way d^6.

k^4. Change of way for establishing the communication between the accommodation way and the locomotive shed.

l. Covered shed, with ways for carriages of every description.

l^1. Painting.

l^2. Joinery.

l^3. Coach making.

l^4. Mounting.

l^5. Office.

m. Carriage way for shifting truck.

n. Office of the engineer of the works.

n^1. Office of the constable of the workshops, and of the master of the same.

n^2. n^3. Forges.

n^4. Engines, tools, and adjusting.

n^5. Fixed engine.

n^6. Tool house.

n^7. Tinmen and coppersmiths.

n^8. Joiners and modellers.

n^9. Sawyers.

n^{10}. Apartment of master carpenter.

n^{11}. Workshop and area of the carpenters.

n^{12}. Covered shed for rechanging the wheels.

n^{13}. Court and timber yard.

n^{14}. Do. do.

p. Turnplate placed in the centre of the polygonal building, and disposed as shown in Plate 33, "Third Series of Railway Practice."

p^1. Office of the constable of the Rotunda.

p^2. Apartment of the chief engineer.

s. Office of the guards of the storehouses.

t. Watchbox of the switchman.

t^1. Watch-box of the porter performing the office of gate-keeper at the road crossing the railway obliquely on a level at the end of the station, as shown in the plan.

FIG. 2.

Plan on the level of the ground.

a. *Peristyle* on the road to Maîne.

a^1. Vestibule with barriers for directing the travellers.

a^2. Ticket office.

a^3. Staircase by which travellers ascend to the waiting rooms.

a^4. Small staircase which establishes a communication between the ticket office and the office of the administration, from the ground floor.

a^5 and a^7. Passage followed by travellers descending from the omnibuses to reach the staircase of the waiting rooms, after having exhibited their tickets at the bottom of the staircase a^7.

a^6. Furnace-room.

a^8. Exit staircase for passengers.

a^9. Exit gate from the omnibus court.

a^{12}. Exit gate on the road to Maine.

a^{11}. Entrance gate of the company. The porter's lodge is placed at the side of this gate, under the staircase of the waiting rooms, the kitchen being under the staircase of the company.

a^{11}. Staircase conducting to the office of the company, on the *entresol.*

a^{14}. Wood house.

a^{15}. Luggage office. The omnibus court communicates with this office.

Plan on the level of the *entresol* :—

a. Staircase conducting to the *entresol* floor.

a^1. Antechamber and passage conducting to the office.

a^2. Hall for the meeting of the counsel, and saloon of the directors.

a^3. Private room of the directors.

a^4. Private room of the secretary of the counsel, performing the duties of cashier.

a^5. Office for two clerks.

a^6. Ditto, ditto.

a^7. Staircase conducting to the waiting rooms, and passing under the office, a^6.

a^8. Private room of the superintendent of police. The floor of this room is a little lower than the floor of the *entresol*, on a level with the landing of the stairs.

a^9. Safe.

a^{10}. Safe.

a^{11}. Private room of the comptroller, placed under the exit staircase a^{12}.

a^{12}. Exit staircase.

a^{13}. Small staircase conducting from the office of the company on the *entresol*, to the ticket office on the level ground.

a^{14}. Passage conducting from the office of the company to the stair-case of the station a^1.

a^{15}. Staircase conducting from the *entresol* floor to the station.

a^{16}. Urinals.

a^{17}. Water-closets for the use of the officers of the company.

References to Section :—

a. Omnibus court.

a^1. Covered footway of the omnibus court.

a^2. Vestibule at the bottom of the exit staircase.

a^3. Staircase of the waiting rooms.

There is a vestibule and a ticket office between a^2 and a^3.

a^4. Board office.

a^5. Private room of the secretary to the board.

a^6. Office for two clerks.

a^7. Ditto, ditto.

a^8. Landing of the staircase of the waiting rooms.

a^9. Private room of the superintendent of police.

a^{10}. Second class waiting room.

References to the General Plan of the Versailles Station (left bank) :—

A. The mayor's avenue.

B. Fixed iron railing.

B^1. Moveable iron railing, or gates.

C. Court.

D. Building forming the waiting rooms, ticket office, &c.

E. Garden.

R. Cisterns.

M. Privies.

H. Building for the collectors, &c.

K. Small forge for repairing.

I. Court for the use of goods.

T. Coffee-house.

L. Gardens extending the length of the stations.

d. Vestibule with gate, for accommodating and guiding the travellers who arrive from the court, C, to a staircase placed between d^1 and d^2.

d^1. Luggage office.

d^2. Confectioner's shop.

d^3 and d^4. Ticket office.

d^5. Portion of the waiting rooms intended, by means of a gate, for travellers of the first class.

d^6. Another portion, intended for travellers at the stations.

d^7. Third portion, intended for travellers of the second class.

The travellers go out by different doors upon the platform, *e*.

e e e. Departure platform.

e^1 e^1. Arrival platforms.

$f\, f^1\, f^2\, f^3\, f^4$. Turnplates upon the old system.

g. Departure line.

g^1. Arrival line.

g^2. Accommodation way for engines, with pit and hydraulic crane, *k*.

$p\ p^1\ p^2$. Change of way for establishing the communication between the way g^2, and the ways, g^3 g^4 g^1 and *g*.

$p^3\ p^4\ p^5\ p^6$. Change of way for establishing the communication between the arrival way g^1, and the departure way *g*.

h^1. Office of the collectors.

h^2. Passage for the travellers arriving at Versailles.

h^3. Superintendent of police.

h^4. Station master.

Plate 48.

Details of Stations.—Dublin and Kingstown, and Leeds to Selby Railways.

References to the general plan of the Dublin and Kingstown Railway Station:—

This station is situate in the interior of the city. It is 6^m (19 feet 8 inches) above the natural soil, and crosses the streets upon bridges consisting of single arches where the width is narrow, and with three arches where the streets are wide.

The travellers enter into the vestibule, a^1 and a^2, by two doors, one of which is intended for travellers of the first class, the other for travellers of the second class. It consists, also, of two offices—one for travellers of each class. The staircases placed opposite the letters a^1 and a^2 serve for travellers of each class, who are thus separated. They ascend by these staircases into the waiting-rooms placed on the first floor, level with the line.

The luggage is deposited in the hall a^3, and carried from this hall to the level of the railway by a small staircase.

The travellers again remain separated upon the platforms. Those of the first class promenade on the platform D D, which is separated by a balustrade (shown by a double line in the figure) from that of the second-class travellers, who promenade upon the platform H. The level of the platforms is 1^m, (3 ft. 3 in.,) or $0{\cdot}80^m$ (2 ft. 7 in.) above the rails. They are paved, and rest upon an embankment, upon which there is a bed of concrete, or of rough masonry, laid with hydraulic lime. The communication is intercepted, on the side of the line upon which the travellers require to pass, by balustrades. The way along the platform H D is the departure line. The contiguous way along the platform F is the arrival line. The two others are the accommodation ways.

The travellers arriving pass over the drawbridge p and p^1 to go upon the quay E, at the extremity of which there is an exit staircase. Those who wish to take carriages go upon the incline B. The drawbridges are inclined upon the way, as shown, whenever it is necessary.

They are formed after such a plan, that they can be easily removed when the train is discharged and the crowd has dispersed; the passage of the engines and the trains may then be resumed. The engine is detached upon its arrival at the head of the train; it passes upon the turn-plate situated at the extremity of the arrival line; it is then directed upon the accommodation line provided for the engines near the hydraulic crane G and the coke depôt, which is at H, (behind which there is a reservoir;) it there takes its supply of water and coke, and re-

passes by crossings to the arrival line, where it retakes the train; it is afterwards directed to the departure way, passing upon the switches, and the train is conveniently placed upon the departure line. It, however, presents the inconvenience of taking the carriages of the first class to the platform of the lower ones, and *vice versâ.*

References to the Longitudinal Section:—

a. Vestibule.

a^1. Luggage office.

a^2 and a^3. Waiting-rooms.

a^4 and a^5. Covered portion of the station.

References to the General Plan of the Leeds Station on the Leeds and Selby Railway:—

A. Building containing office.

B. Storehouses.

C. Court in which a portion of the goods is deposited, which is required to go to Leeds.

E. Shed where another part of these goods is deposited.

D. Slope conducting from the court to the shed.

F. Office.

V. Departure line for goods.

V^1. Arrival line.

V^2. Way for the departure of travellers.

V^3. Ditto, arrival ditto.

There are no platforms, and the ways are covered, as shown in the Figures.

H. Line serving to establish a communication between the way V^3 and the storehouse B.

K. Court, the ground of which is 4^m (13 feet) below the level of the rails.

The goods are deposited in this court, or in the warehouse B, when they are first delivered. The cranes serve to raise the goods from the court, or from the warehouse, and to place them upon the vehicles employed in removing them.

L and L^1. Ways for the arrival of coal.

These ways, L and L^1, are carried upon transverse walls 4 metres (13 feet) high. The coal wagons are of the same kind as that represented in Plate 29, of the Strasbourg and Basle Railway, and discharge, by means of a trap placed below, into the compartments (24) between these walls or vaults. These small storehouses belong to some of the principal merchants of Leeds.

I. Way for the transport of lime.

The wagons employed are like those for the coal.

The lime falls into the compartments, but the line is covered, whilst the ways L and L^1 are not.

N. Workshops for the repairs of engines and carriages.

n. Forges and adjusters.

n^1 and n^2 Mounting engines.

n^3. Workshop for repairing carriages.

n^4. Ditto for painting.

n^5. Tower and double forge.

n^6. Fixed engine and reservoir.

On the first floor above n^5 are the offices and warehouses.

O. Small auxiliary shed.

P. Skew-bridge with columns.

References to Enlarged Plan :—

a. Ticket office.

a^1 and a^2. Goods label office.

a^3 and a^4. Staircase conducting to the railway, which is on a level with the first floor.

There are no waiting-rooms. Travellers who wait for the departure of the train are kept under the portico, or under the large shed.

a^5. Appendage.

General Plan of the Selby Station on the Leeds and Selby Railway :—

V and V^1. Ways for the arrival of goods wagons.

V^2. Way for the arrival of travellers.

The goods wagons are separated from the passenger wagons at H: the former follow the ways V or V^1, and the latter follow the way V^2.

The travellers descend by V^2 under the great shed which covers all the ways.

The goods are discharged partly under the shed and partly at the extremity of the ways V and V^1 in the buildings.

Depôts for Goods :—

The lime and coal wagons, leaving the train at K, pass on to the ways V^8 and V^9, and are discharged at the covered pits at D, or at the fender stops placed at the extremity of these ways V^8 and V^9.

The ways V^3 V^4 V^5 and V^6 are the departure and accommodation ways for the shedding.

They prepare the passenger trains upon the way V^3, and the goods trains on the ways V^5 and V^6, or upon the way V^6 only. The way V^5, therefore, remains open for the use of engines, and the goods wagons are united to the passenger wagons after changing the way.

The way V^7 establishes a direct communication between the way V^3 and V^6.

E and E^1 are reservoirs for supplying the engines.

F. Office of the superintendent.

a. Building forming the ticket office and lodgings of the officials.

Plate 49.

Strasbourg and Basle Railway.—Intermediate Stations of the Second and Third Classes.

References to the Detailed Plan of the Station of Rouffach :—

A. Vestibule.

B. Waiting room.

C. Ticket office.

D. Office of the overseer of the line.

E. Parcel and luggage warehouse.

F F^1. Arrival and departure platforms.

G G. Privies.

H H. Hydraulic crane.

I. Building for the pump. Depôt for tools of the line.

K. Goods shed.

L M N. Siding employed for housing the loaded wagons that require to be attached to the trains ; also the empty wagons.

P P P. Ground belonging to the station.

Station at Eguisheim—Ground plan : —

A. Waiting room.

B. Receiver's office.

C. Warehouse.

Upper floor, containing the lodge of the receiver.

Detailed plan of the station at Merxheim :—

A. Building, forming the station, which is at the foot of an embankment.

B B. Staircases leading to the platforms.

C and C^1. Arrival and departure platforms.

Ground Plan of Building:—

A. Waiting room.

B. Office.

C. Warehouse.

The upper plan serves for the receiver's lodgings.

Plate 50.

Details of Railway Stations.—Intermediate Stations of the First and Second Classes.

References to the General Plan of the Watford Station (first class) formed in a cutting upon the London and Birmingham Railway:—

A. Court for carriages and omnibuses bringing travellers.

B. Building of the offices and waiting-rooms, with interior court, represented upon a larger scale above.

C. Departure platform.

C¹. Arrival ditto.

Plan of the Building of the Waiting Rooms:—

A. Court.

B. Office and waiting room.

C. Interior court.

D. Water-closets.

E. Entrance staircase.

G. Exit staircase.

H. Guards' lodge.

I. Coal depôt.

K. Well and pump.

L. Steam engine.

M. Coke depôt.

N. Machinist's court.

O. Hydraulic crane.

General Plan of the Tring Station (first class), being on an embankment, upon the London and Birmingham Railway:—

A. Waiting-room and appendages (see the ground plan).

B. Station for carriages.

C. Shed.

Ground Plan of the Buildings:—

A. Ticket office and small waiting room.

B. Building of the reservoir.

C. Interior court.

D. Building, with iron roof, containing a waiting room.

H. Hydraulic crane.

E. Departure staircase.

L. Arrival ditto.

F. Departure platform.

General Plan of the Coventry Station (first class), in a cutting upon the London and Birmingham Railway :—

A. Building forming the waiting rooms and appendages.

B C O. Steam engine, reservoir, and shed.

B. Plan taken on the level ground. The plan on the first floor is the same.

On the level ground there is an office and chamber.

On the first floor, above the office B, is a fixed steam-engine, and above the engine a plate-iron reservoir.

On the first floor at C, second office and stoker's apartment.

O. Shed for carriages.

P P. Hydraulic cranes.

There are vaults under the building where coke is stored.

Enlarged Plan of the Building A:—

A. Passage.

B. Waiting room.

C. Vestibule of ticket office. The travellers enter by the passage A into the vestibule C to take their tickets, passing before the office D; they then proceed into the waiting room B.

E. Passage.

F. Ante-chamber.

L. Men's water-closets.

K. Ladies' water-closets.

G. Interior court.

H. Departure staircase.

P. Arrival ditto.

General Plan of the Wolverhampton Station (of the First Class) upon the Grand Junction Railway:—

This station differs from the preceding in being arranged for the reception of goods.

A. Building forming the waiting room.

B C. Sheds for housing the carriages and goods.

B. Portion for housing goods.

C. Ditto, ditto, carriages. The ways v and v^1 are placed in pits at a depth of about 1 metre (3 feet 3 inches) below the level of the court D, so that the platforms of the goods wagons being at the same level, the loading and unloading is easily effected. There is a platform between the two ways, v and v', the level of which is the same as the court.

D. Court intended principally for loading and unloading goods.

E. Departure platform.

F. Arrival ditto.

Enlarged Plan of Building A:—

A. Ticket office.

B. Waiting room.

C. Ladies' saloon.

D. Coal store.

E. Privies.

General Plan of a Small Station on the London and Southampton Railway:—

The building contains two parts only, viz., a ticket office, and a small waiting room, by the side of which are the privies.

General Plan of the Newton Station, upon the Liverpool and Manchester Railway:—

A. Office and waiting room for travellers going to Liverpool.

B. Ditto, ditto, Manchester.

C. Carriage shed.

Enlarged Plan of Building:—

A. Ticket office.

B. Small waiting room.

General Plan of the Ditton-Marsh Station on an Embankment upon the London and Southampton Railway:—

A. Ticket office.

B. Waiting room.

C. Court principally appropriated for omnibuses and carriages.

D. Departure platform.

D[1]. Arrival ditto.

E. Incline for travellers.

F. Ditto, carriages.

H. Loading place of carriages upon the wagons.

General Plan of the Woking Station on the London and Southampton Railway:—

A. Ticket office.

B. Waiting room.

C and D. Water closets.

G. Shed for carriages.

H. Shed for an engine.

Plate 51.

Stations.—London and Birmingham Railway.

General Plan of the Euston Square Station, London, as originally laid out:—

Cabs and other special vehicles, bringing passengers, enter by the grand Grecian portico P, set them down beneath the *peristyle*, and then turn round in the widest part of the court on the other side, and depart by the entrance P. The foot passengers also enter by the same portico; travellers of the first-class enter the office by the left door, and, after procuring their tickets, pass through the corridor E to the waiting room C.

Those of the second class enter the office by the other door, and after having obtained their tickets, pass into the waiting room B. The urinals are placed at the extremity of the building.

The passengers wait on the platform of departure J until the departure of the trains. D and E are corridors which form the communication between the portico and the platform of departure. The stairs placed in these corridors lead to a second floor, where the Company's offices are placed. The passengers carry any light luggage with them into the waiting rooms.

Special vehicles, for transporting horses and heavy baggage to the railway, enter by the gate P[1]; they are entered at the offices K and L, and wait the time of the train starting in the court for loading R. They are placed on the trucks by means of turn-tables.

J. Platform of departure.

J′. Platform of arrival.

The vehicles or omnibuses waiting for the arrival of passengers are stationed in the court H′, arriving and departing by the gate P‴.

V′ and V″ are the ways to the sheds. The carriages are passed, from one of these roads to another, by means of turn-tables. The ways are covered with iron roofing.

N is a large shed, with two floors, for the worn-out and unemployed carriages, or for the new ones in reserve.

Two buildings are represented in the plan for waiting-rooms, although only one has been built. The station was arranged to receive the second, which was originally intended for the Great Western Railway.

The locomotive engines did not formerly pass into the station, which is situated at the foot of an inclined plane, 3000 metres (3281 yards) long. The grand depôt for goods is at the head of this inclined plane; the workshop for repairs, and the sheds for the locomotives, carriages, and goods trucks, also the two fixed engines which originally worked the plane.

General Plan of the Station at Birmingham:—

The irregularity of the country did not permit of this station being arranged so symmetrically as that of London. The arrangements for the convenience of passengers are, however, made in a manner exactly similar.

The foot passengers, as well as the carriages, enter by the gate A; they turn at B, and depart at A.

C is the office for obtaining tickets.

D is the first-class waiting room.

F that of the second class.

E the ladies' waiting room.

G is the platform of departure.

G′, that of arrival.

The heavy luggage is brought in by the gate H, passing before the offices I, and is loaded on the turn-tables in the court K.

V. Departure line.

V^5. Arrival line.

V′ V″ V‴ V^4 are ways to the sheds.

The number of ways to the sheds is greater than at the London station, because the sheds are smaller.

U. Court of arrival.

The system of management at this station is precisely the same as at the London station.

The iron roofs have a greater space, and extend along the ways of the station and the platform to a length of 76 metres.

This station is on a level with the ground, and the engines use it. The repairing shops and sheds are therefore placed at R, in the immediate neighbourhood.

The locomotives enter into the rotunda, by the ways V^6 and V^7, and are passed on to any one of the ways terminating therein, by means of a turn-table placed in the middle.

S and S′ are forges, and T and T′ are the chimneys of two fixed engines, which are placed in an underground chamber. The engines raise the water from a canal into the reservoir placed above the forges, by means of pumps, and which supplies the tenders with water.*

K and K′. Coke sheds. When a locomotive is cleaned, greased, and repaired, it takes in coke and water, and is brought to the head of the train by the way V^6.

The goods trucks leave the passenger train at A, and enter the goods depôt at B C. They cross a road, passing over by means of a bridge, and then traverse a simple level crossing, and are brought under the great sheds at C C C C, by means of turn-tables.

d is a building containing the offices belonging to the goods department; a magnificent hotel at the entrance of the station, containing the offices for the luggage of passengers on the ground floor, and the apartments of the directors and other officials, on the upper floors.

Plate 52.

Strasbourg and Basle Railway.—Station at St. Louis.

References of the General Plan of the St. Louis Station:—

A. Guard house.

A′. Custom-house offices.

B. Building forming the offices and waiting-rooms.

B′. Sheds and platforms for the arrival and departure of the travellers.

C. Sheds for loading goods.

* The extension from Chalk Farm to Euston Square, being now worked by locomotives, these engines and chimneys have been removed.

C′. Sheds for unloading goods.

D. Engine sheds and repairing shops.

E E. Warehouses, with office.

F. Building for coke, stone, and reservoir.

G G G. Platforms for loading and unloading carriages.

H. Water closets.

Enlarged Plan of Entrance Building:—

a. Luggage inspection room.

b. Passengers' ditto, ditto.

c. Office.

d. Waiting-room for travellers of the first class.

e. Office of the station master.

f. Ticket office.

g. Vestibule.

h. Waiting-room for travellers of the second and third class.

i. Luggage office.

k. Discharge.

Plate 53.

Station of the Strasbourg, Basle, and Mulhouse Railway.

References of the General Plan of Station:—

A. Building forming office and waiting-rooms.

B. Office of customs.

C. Office of the Superintendent of Police.

D. Water-closet.

E. Ditto.

F. Porter's lodge.

G. Shed and workshops for slight repairs.

H. Appendages of ditto.

I. Reservoir and steam engine.

K. Cattle shed.

L. Old temporary station.

M. Shed for the use of goods.

N. Ditto, ditto.

O. Urinal.

P. Hoist bridge.

V. Departure way.

V^1. Arrival way.

The intermediate ways are for the accommodation of the shedding.

The ways V^2 and V^3 are intended for the use of goods.

The ways V^5, V^6, and those which are not specially indicated, serve for the reservoirs and repairing shops.

a. Vestibule.

b. Ticket office.

c. Passage.

d. Staircase for ascending to the last.

e. First class waiting-room.

f. Second and third class ditto.

g. Luggage office.

h and *k.* Station-master's office.

i. Guard-house of the officers of the customs.

l. Water-closets.

m. Superintendent of police.

In the ground plan of the goods shed, the goods are brought and removed by the road R, and they are loaded when they are placed upon the platforms of the shed.

Plate 54.

Vienna and Raab Railway, Austria.—The Vienna Station.

The station of the Vienna and Raab Railway, represented upon this Plate, covers a triangular plot of ground of about 32,000 square toises (21,000 square metres.)

It is in the shape of an isosceles triangle; the two equal sides nearly forming a right angle, and meeting near the town of Vienna.

Two branches of the Vienna and Raab Railway follow these sides; one going to Presbourg on the right, the other to Neustadt on the left. Similar buildings are shown at the extremities of each of these branches, where carriages stand. One of these depôts, that on the Neustadt Railway, is only just constructed.

The two branches of the Vienna and Raab Railway—viz., those of Presbourg and of Neustadt, are united by an auxiliary line, as shown.

A is the plan of the depôt of the Neustadt branch, at the level of the ground, it comprises not only the building of the waiting-rooms, but the whole of the covered hall.

B is the plan at the level of the first-floor of the depôt of the Presbourg branch, comprising the covered hall.

The space *a a* comprised between the fronts of the two buildings, contains the waiting-rooms, formed as a large space, in which the carriages which bring passengers arrive, and are stationed.

C. Building of three stories, containing a refreshment room on the ground-floor, and the company's offices; also those of the engineers and architects on the upper floors, and a large hall for general meetings.

The front of this building, looking towards Vienna, commands a magnificent view of the city.

D E F G and H. Large workshops for repairing engines, and wagon sheds.

I and J. Projected sheds.

L M K. Lodgings of the guards.

N O P and Q. Buildings for the supply of fuel and water, and sheds for locomotives.

R. Office of the engineer of the works.

S. Depôt for carriages and horses.

We will now detail the different parts:—

We find, from the Plate, that the building containing the waiting-rooms has two stories.

The ground floor consists of the following parts:—

a. Vestibule.

b. Ticket office.

c and *d*. Offices for the labelling of luggage placed under the staircases.

f and *f′* are the staircases conducting to the first floor; *f′* is a staircase by which travellers who have taken their tickets ascend to their waiting-room; *f* that by which travellers who arrive by the train descend.

The gate *g* leads under an arcade *h*, before which the omnibuses are stationed.

The landing-place at the foot of the staircase *f′*, is separated from the vestibule *a* by an iron railing.

There are water-closets at one of the ends of the arcade.

There is a refreshment-room behind the ticket-office.

The arrangement of the first-floor, shown by the building B, exactly resembles the building A.

l, *m*, and *n* are the waiting-rooms for travellers of the first and second class. Those of the third are under the hall.

The platform which surrounds the hall *o* on three sides is covered with asphalte. It is 0^m 19 high (7 inches), and 3^m 50 (11ft. 6in.) wide.

p. A kind of large wooden box, filled with flowers, which serves as a fender-stop.

The turn-plates, which are 7^m 90 (26 ft.) diameter, serve to turn the engine and tender at the same time.

The railway being on an embankment seven metres (23 ft.) high above the ground, there are vaults made under the platforms and railway.

The halls are entirely covered by a roof, after the system of *Viegmann*, a section of which is shown.

The buildings forming the workshops and repairs, D E F, are of two stories.

The ground-floor contains a mounting shop for locomotives at *d*, with ways and the necessary pits, two cranes, and a machine for placing the wheels upon the axles.

d^2. Turners' workshop, containing thirteen lathes and machines of different sizes for boring, four planing machines, four machines for making screws, and several grinding-stones.

d^3. Two high-pressure steam engines, each 12-horse power, provided with three furnaces.

A well is placed at *s*, and a pump to raise the water to the reservoir placed above the roof, for the boilers, the workshops, and the supply for the locomotives.

There is a ventilator in the same building d^3, which furnishes the necessary draught to two furnaces (*Wilkinson's*) placed in the foundry F.

d^5. Building containing 14 forges, supplied with a draught from the ventilator, a pair of shears, a boring machine, another for cleaning and bending the boiler plates, a presser, and a hammer.

d^5. Two cartwright's workshops, containing two circular saws.

The architect's office and a workshop for engines are placed above the ground-floor. The locksmith's department is above the workshop d^2; the pieces from the forge are finished and adjusted there; nine small machines for turning, planing, and boring, are placed there. The model rooms are on the first-floor above the mounting workshop; a joiner's workshop, with a new circular saw, and a designing room. The buildings d^1 d^2 d^3 are heated in winter by the waste steam of the fixed engines.

E. A foundry, containing four forges and a furnace for reheating the plate iron.

F. A foundry, containing two of Wilkinson's ovens, two stoves, and a casting workshop.

There is a machine for breaking the cast iron before the building forming the foundry.

The wagon sheds G H I and J may be considered as appendages of the repairing workshops.

The buildings O N P Q relate more especially to the reservoir, consisting of a building O, in which the reservoir (properly so called) is placed.

M P are engine sheds; a small repairing workshop is placed in this building.

Finally, the building Q contains, besides the Company's office, an apartment for the chief engineer. All the buildings of the station represented in the Plate were constructed upon an embankment of 7^{m} 50 (24 feet 7 inches) above the mean level of the Danube, the quantity of water required for the use of the locomotive engines and workshops is not therefore procured without great difficulties. A considerable quantity is raised by two steam engines from the workshops to the reservoir, placed upon the roof, and discharged by an aqueduct into the reservoir O. The water of this reservoir is heated in winter by two furnaces. The repairing workshop sometimes in the summer consumes a part of the water necessary for the reservoirs O; a well has been sunk to furnish the proper supply. The water of this well is raised by an additional engine. The wheels of this locomotive turn upon two fixed friction rollers instead of rails, as on the Southampton Railway, and therefore do not advance. The carriage sheds are constructed of cut stone.

Pits of 0^{m} 71 (2 feet 5 inches) depth, faced with bricks, have been established between the rails for facilitating the inspection of the works.

The way V is a departure line. V′ arrival ditto. It is seldom that the passengers ascend or descend under the hall; the trains generally stop at the entrance, so that these serve more particularly for turning.

The ways V″ and V‴ are the ways to the shedding, and for loading and unloading.

The ways V^4 and V^5 are intended for the use of goods. They are level with the gate X, and rise from this gate to the building R, with an inclination of 1-27th to 1-30th.

The way V^6 leaves the workshops V^8 and V^9 before it unites the Presbourg and Neustadt Railway, being only placed upon a part of their length, serve here for ways to open shedding.

The ways V^{10} V^{11} and V^{12} and those with which they communicate by turnplates, leave the buildings N O P Q.

The additional locomotive engine is generally stationed upon the way V^{12}.

Lastly, the ballast wagons are placed upon a siding V^{13}.

p 2

Plate 55.

Paris and Orleans Railway.—Etampes Station.

References to the General Plan of the Transit and Accommodation Ways, and the Buildings in use at this Station:—

FIRST BUILDING, (FOR PASSENGERS.)

A. Entrance vestibule.

B. Ticket office.

C C C′ C′. Waiting-room for Orleans and Paris.

D. Luggage register office.

E E. Travellers' water-closets.

SECOND BUILDING OPPOSITE.

F. Refreshment room. The time of stoppage of the trains at this station being always ten minutes, at the least, the travellers can alight, and partake of a cold collation, which generally consists of cakes and provisions, ready laid out upon a large side-board, of about 10 metres (32 ft. 9 in.) in length.

G. Office of the station master.

H. Apartment of the superintendent of police.

THIRD BUILDING, (FOR WAGONS.)

I. Shed for 12 wagons, but which can easily contain 18.

FOURTH BUILDING, (FOR LOCOMOTIVES.)

K. Rotunda for housing 16 locomotives and tenders, with pits 8 metres (26 ft. 3 in.) long; is covered with slates, and lighted below with a large window, opposite each way, by skylights in the roof, and lastly, by a high lantern.

K′. Principal entrance.

L. This part of the rotunda only is surmounted by a floor, and serves as the apartment of the chief engineer and for the workmen employed in the repairs. Slight repairs only are done at this station, all the large and important works are performed at the principal workshops at Paris, where large and spacious workshops are established.

There is a reservoir of water on the first-floor—that is to say, 5^{m} (16 ft. 5 in.) above the ground, of 40 cubic metres (52 cubic yards) capacity, a well below of $1{\cdot}50^{m}$ (4 ft. 11 in.) diameter, which supplies it.

FIFTH BUILDING, (FOR GOODS.)

N. Goods depôt.

O. Paved part for rolling.

P. Raised platform for the goods depôt.

P′ and P′. The same platform, which is prolonged uncovered to each side of the building.

Q. Depôt of the post-chaises.

R. Accommodation ways.

S. Paris to Orleans way.

T. Orleans to Paris ditto.

U. Exit of the passengers who arrive at this station; the omnibuses are stationed without, for the different parts of the neighbourhood.

Order of Transit of the Engines at the Station of Etampes:—

The passenger train going from Paris to Orleans will follow the ways 2, 3, 8, 22, and will stop before reaching the point 29.

The engine will quit the train to be housed, and will follow the lines 29, 25, 23, 9, 7, 5, 6, 11, 15, 14.

The engine which retakes the Etampes train at Orleans, will be stationed on the lines 13, 10; it will take the head of the train, following the lines 10, 19, 23, 25, 29.

If the train is required to ascend the slope of 0·008 metres (1 in 125), it is necessary to employ an assistant engine, which will be that coming from Paris.

Instead of housing itself, it will stop and take water at this place by means of an hydraulic crane placed for this purpose. Upon arriving at the head of the slope, this engine will take the change of way of Guillerval, and enter the depôt by the way T (otherwise called the Orleans to Paris line) to the point 10, and depart from this point by the lines 10, 7, 5, 6, 11, 15, 14.

In case the ways 15, 14, leading to the depôt, should be in use, the engine will follow the lines 10, 13, 14.

The passenger train going from Orleans to Paris, will follow the way T, near the point 24; it will stop, and the engine pass to the rotunda, following the lines 24, 19, 10, 7, 5, 6, 11, 15, 14.

The engine which will retake the train will be stationed upon the lines 13, 10, and will go to its place at the head, upon the line 19, 24; the train will follow the line T.

The goods train coming from Paris to Etampes will stop upon the ways S at the point 3, the engine will detach itself from the train, and will proceed to place itself behind, to drive the train, following the lines 3, 4, 1, 2.

The train will enter into the station following the line 3, 4, 5, 6, 12, 16, 16, (*twice.*)

The engine will return and enter the rotunda, following the lines 16, 12, 6 11, 15, 14.

The goods train from Etampes to Paris will be formed upon the lines 17, 17, (*twice*,) of the station.

The engine, proceeding to the head, will leave the rotunda backwards, and follow the lines 14, 15, 11, 17.

The direct goods train from Paris to Orleans will follow the way S, and change the engine, or will take on an assistant one, if it is necessary, like the direct passenger train.

If it is desirable to leave it at the station, it will pass the point S, backing and taking the siding ways 36, 34, 31, 25. It will re-enter the lines S by the change of ways 36, 38.

The goods train from Orleans to Paris will follow the way T, and cha the engines like the passenger train.

If they wish to leave it at the station, it will take the way R at the point 41, and will retake the way T by the change of way 39, 37.

(22, 21), (24, 20) Ways for disengaging carriages.

(18) Ways to the shedding.

(26, 27, 28) Reserve ways for rapidly adding carriages to the train going to Paris.

(21 A), (21 B) Ways for loading and unloading postchaises.

(21 C) Sheds for post-chaise trucks.

Crossing places:—

There are three crossings at right angles, indicated by the letters *a b c*.

Four at the angles 35° 47′, 31° 25′, 52° 30′, 47° 40′ shown by the letters, *d e f g*.

Crossing rails:—

There is one crossing at the angle of 7° 58′, shown at H.

Two ditto, ditto, 8° 39′ shown at *f k*.

Twenty-two ditto, conformable to the model, at the angle of 5° 37′.

Twenty-five changes of way.

Plate 56.

Workshops of the Strasbourg and Basle Railway at Mulhouse.

References to the General Plan of Workshops:—

A. Principal building.

B. Forges (eight fires).

C. Stores and vaults for the making of yellow grease for the carriages. The building being upon an embankment two metres (6ft. 7in.) high, above the ground, the vaults which are alluded to are on the ground-floor, therefore on a level with the ground.

D. Privies.

There is a coke store on the left, near the railway, which is not represented upon the plan; and an engine shed to the right, near the building C, on the railway from Mulhouse to Thann, a foundry, and a warehouse.

The building A is subdivided in the following manner:—

a. Shed and mounting shop for thirteen locomotives.

b. Workshop of engine tools.

c. Shed for tenders, and warehouse.

d. Steam engines and boilers.

e. Mechanical engineer's office, and porter's lodge.

The first-floor of the building *d* is occupied by the polishers' benches, and by small towers; it also serves as a workshop for making models.

The first-floor of the building *e* contains the office and the foreman's apartment.

See the details of the great work of MM. Bazaine and Chaperon, upon the Strasbourg and Basle Railway.

Plate 57.

Paris and Orleans Railway.—Paris Station No. 1, *for Passengers and Luggage.*

References to the Plan of the Company's Office:—

The letter a is for the ground floor.

a^1. Great gate.

a^2. Court.

a^3. Entrance vestibule.

a^4. Antichamber.

a^5. Cashiers.

a^6. Office of the foreman of the works.

a^7. Controller's office.

a^8 a^8 a^8. Office and apartment of the engineer of the works.

a^9 Guard-house.

a^{10} a^{10}. Apartment of the cashier.

a^{11}. Accompt office.

a^{12}. Privies for the workmen.

a^{13}. Book keeper.

a^{14} a^{15}. Office of the cashier.

First Floor:—

b. Architect's apartment.

b^{1}. Workshop of the designers.

b^{2} b^{3}. Office for hearing complaints.

b^{4}. Apartment of the director of ditto.

b^{5}. Apartment of his principal clerk.

b^{6}. Ante-chamber.

b^{7}. Board room.

b^{8} b^{9}. Office and apartment of the chief engineer.

b^{10}. Passage.

b^{11}. Office of the under engineers.

b^{12}. Keeper of the records.

b^{13}. Workshop of the draughtsmen or engineering designers.

b^{14}. Lodging of the Guard.

Upper Floor:—

c. This floor serves only for the apartments of the director. It has two sleeping-rooms, a large and small parlour, a boudoir, and working-room, dining-room, office and kitchen.

c^{1}. Roofs, under which are the garrets and chambers of the servants.

Workshops for the small repairs of wagon (joiner, painter and glazier, locksmith, coach-builder, upholsterer, and inspector.)

e. Court for loading the post-chaises and goods speedily.

e^{1}. Court for the departure of travellers.

e^{2}. Court for the arrival of ditto.

e^{3}. Court for embarking and disembarking diligences.

e^{4}. Court for the arrival of goods, conducted with great speed.

e^{5}. Court for the arrival of post-chaises.

f. Hall for the travellers who have luggage.

f^{1}. Waiting-room for passengers of the Orleans line.

f^{2}. Waiting-rooms for passengers of the Corbeille line.

g. Register office of luggage and parcels.

g^{1}. Orleans ticket office.

g^2. Ticket-office for Corbeil.

h. First class waiting-room for Orleans.

h^2. Second and third ditto.

h^3. Ditto for Corbeil.

i. Covered passage for going from the luggage booking-office to the waiting-halls.

i^1 and i^2. Offices of the correspondents of the carriages and boats with the railway.

j. Passengers' departure platform.

k. Ditto arrival from Orleans and Corbeil.

l. Cranes of the system of M. Arnoux, for loading and unloading diligences.

m. Sheds for sheltering the bodies and horses of these deligences.

n. Shed for unloading luggage and parcels speedily.

o. Hall for the distribution of luggage.

p. Waiting-office for the luggage.

q. Toll.

r. Inspector of police.

r. Surgery.

s. Gasometer.

t t^1 t^2. Water-closets.

S. Paris and Orleans way.

T. Orleans and Paris way.

All the other ways are either accommodation or siding ways.

Order of the Transit of the Engines and Trains in the Paris Station:—

The train will leave following the lines 8 (twice), 13 (twice), 17, 22, 35, 40, 41. The train coming from Orleans will follow the lines 42, 34, 29, 23, 18, 16, (twice), 9.

An engine leaving the workshops, to put itself at the head of the passenger train from Paris to Orleans, will follow the lines 39, 33, 31, 30, 27, 20, 16, 15, 14, 13, 8. Where there is a great transit of trains, 39, 32, 31, 30, 29, 23, 18, 11, 14, 13, 8.

The engine, after having left the train, will return to the depôt, following the lines 5, 4, 15, 16, 20, 27, 30, 31, 39.

The goods train will leave following the lines 26 (twice), 33, 40, 41, and it will continue on the way S.

The ways (43—43,) and (44—44,) are accommodation ways.

The goods train coming from Orleans, will go to the goods station following the lines 42, 41, 40, 33, 32, 25 (twice).

The engine will return to the depôt following the lines 25, 24, 21, 28, 35, 40, 41, 42, 36 (twice); 36, 31, 38, 39, or the lines 25, 24, 21, 19, 8, 13, 14, 15, 16, 20, 27, 30, 31, 38. 39.

The engine going to put itself at the head of the goods train, will follow the lines 39, 38, 31, 36 (twice); 33, 42, 41, 40, 33, 26 (twice).

The change of way 27 is intended to shift the wagons into the repairing workshops.

The platforms 6 and 7, serve to place the trains speedily upon the departure way.

The platforms 1 and 10, serve for loading and unloading the post-chaises.

Plate 58.

Paris and Orleans Railway Station at Paris.—No. 2. Goods Depôt and Workshops.

References to the Detailed Plan:—

a. Entrance from street, and exit for wheel carriages.

a^1. Porter.

a^2. Court.

a^3. Water-closet for coachmen.

A. Goods depôt, plan of foundations 3 metres (9 feet 9 inches) below the rails.

A^1. Plan at the height of a man.

A^2. Projected enlargement. The foundations of this enlargement have been made previous to the laying down of the rails.

a^4. Large gates, with a clear way of 9 metres (29 feet 6 inches) opening for the carriages.

a^5. Paved part, and covered with the common roof of the building, where is effected the loading and unloading of the carts, drays, trucks, &c.

a^6. Quay of one metre (3 feet 3 inches) above the rails for the goods depôt.

a^7. Part reserved for the movement of wagons in loading and unloading.

a^8. Rolling gates, for the entry and exit of wagon.

a^9. Sheds for sheltering cattle.

a^{10}. Cranes for placing carts ready laden upon the wagons called *maringottes.*

a^{11}. Quay, or depôt, for post-chaises of little speed.

B. Bridge over the railway, over which the road passes, and the exterior *boulevard* of Paris.

B′. Wide space, serving for a store-yard for those employed laying down the way in which the crossing and changing places are laid down, and where the rails are deposited.

B″. Shed for the workmen working at the rails.

C. Workshop for the construction of wagons.

c. Workshop for the painting of wagons.

C′. Shed for wagons constructing and repairing.

C″. Temporary ways.

C‴. Courts planted with trees, in which there are depôts for wheels, wood, and other materials.

d. Magazine for bar iron.

d^1. Office of the superintendent of the workshop of the forges.

d^2. Workshop of the forges.

There are sixteen furnaces with one or two fires, and a great furnace for the larger pieces. A ventilator is kept in motion all day, to supply the seventeen forges with draught. There is a second exactly similar, to replace the first, in case of accident; they are 0^m 90 (3 feet) diameter, and make about 2400 revolutions per minute.

d^3. Furnace to heat the tires horizontally.

d^4. Crane, for the service of the principal forge.

d^5. Basin, of 3 metres diameter, and 0^m60 deep, for the tires and the wheels.

A tilt hammer is placed in the middle of this workshop, with a shaft about 25 decimetres long; the weight of the mace at the end of the shaft may be about 100 kilogrammes, (220 lbs.) It receives the movement of an oscillating cylinder placed under it, to which the steam of the common boiler is applied, as required by the forger, by means of a steam-cock at his command. This hammer furnished with two fly wheels, more than two metres diameter, next a small rolling cylinder, for the blades of the springs; a great vice, which is fixed; a square cast iron basin of two square metres, serves to temper the blades of the springs.

d^6. Establishment for the workmen who shape the blade of the springs when cold, to prepare them for steeping.

E. A building in which are two of Beslay's engines, with high pressure vertical boilers. These boilers communicate by pipes, and are established in a pit three metres deep, indicated by the polygonal line surrounding them; they have lately added a third, E, which is the boiler of a locomotive.

F. Steam-engine, with a balance-beam of four atmospheres, by Stehelim and Huber Bistchwiller (Haut-Rhin).

f. Feed wells for the three boilers mentioned above; the band passes over the fly-wheel of this machine, which communicates the movement to a horizontal shaft extending the length of the workshop, G, and which distributes the power.

G. Workshop of adjustment.

Vices and drawers are distributed along the entire length of the windows on each side; working machines, to the number of twenty-five or thirty, are placed in the middle, at points previously selected.

The working machines of this workshop consist of several planing machines, of different degrees of strength, by Whitworth. Among the boring machines, one of Sharp and Roberts is very important, being five metres high; it serves for the small as well as the largest work; a machine to unwedge the wheels; a machine for making screws; a mortice machine, by Sharp and Roberts; a machine to bore a mortice, by Calla, of Paris; ten turning machines, of different sizes, dimensions, and uses, with cast-iron benches; one of them serves to turn the driving wheels, and those of wagons. All these machines are set in motion by the steam shaft; many of them are described in the work of M. Armengaud.

g. Saw-pit, with circular saw.

g^1. The office of the superintendent of the workshops and of the modellers is in this building; the remaining space is occupied by lamps, by a magazine containing a large stock of reserved pieces previously manufactured for the machines and wagons, arranged and disposed in cases.

g^2. Building similar to the last, which is also used for a magazine.

G^1. Mounting workshop, in the middle of which there is a large longitudinal pit, 4 metres (13 feet) wide, with two ways on it, upon which a chariot, g^2, moves, carrying a locomotive to be repaired, which they bring in front, on one of the twenty-four spare ways, g^4, which are each provided with a pit, communicating with a great trench; all these trenches possess the inconveniences of having no stairs.

G^2. Workshop of cast iron and smithy, with two forges.

G^3. Court used as a workshop for carpentry. The wheels taken to be repaired pass over the ways along it.

G^4. Water-closets for the workmen, which are very well arranged.

G^5. Reservoir of water, composed of four cisterns, each two metres high (2 feet 6 inches.)

G^6. Porter and gate for the workmen.

H. Building for residence of the chief of the superintendents of the workshops. It was built before the other buildings, and was not pulled down when the land was bought.

I. Crane of wood and iron, for the service of the workshops, constructed by M. Cavé, of Paris. It will support a weight of twenty tons.

J. A cast iron reservoir of water, four metres above the rails; it is covered and heated in winter; underneath, is an office for engine conductors.

K. Rotunda for sixteen engines and tenders, the dotted lines of the plan and the section show that the middle is not covered. The roofing is light and strong, consisting of iron girders covered with zinc.

k. Coke sheds.

L L L L L. These parts are occupied by large coke depôts; the courts are planted with trees.

M M^1 M^2 M^3. Large carriage-gate, 4 metres wide.

N. House for the guard of the level crossing, and of the Balance bridge *n*. There is a clock, with a large face, at the top of this building.

o. Hydraulic crane for filling the tenders.

Plate 59.

The Paris and Orleans Railway.—The Station at Orleans.

References to the General Plan of the Station:—

A. Plan of the depôt for passengers and waiting-rooms.

B. Plan of workshops and engine shed, (the two ways b and b^1 serve for cleaning the engines).

C. Plan of goods depôt.

D. Cranes for loading and unloading carriages, upon the system of M. Arnoux.

E. Sheds for the horses and the limbers of the carriages.

F. Depôt for post-chaises.

G. Ditto.

H. Entrance-court.

K. Exit ditto.

M. Lateral street for the entrance of the railway.

N. Ditto, exit ditto.

P. Exterior boulevard, moat and rampart of Orleans.

S. Paris and Orleans way.

T. Orleans and Paris do.

Order of Service at the Orleans Station of the Paris and Orleans Railway:—

The passenger train will follow, leaving the lines E, D, C, B, A, and arriving on the lines F, G, H, L.

When the engine goes from the workshops, to take the head of a passenger train, it will follow M K I A B D E, or M K I G C′ C D E.

After having brought a passenger train, the engine will follow the line L O N Y K M in returning to the workshops.

The goods train will follow, leaving the lines V V′ B′ A, in arriving at the lines F Z Q.

The engine, in going from the workshops, will take the head of the goods train, and follow the lines M K I A B B′ V′.

The engine, in returning to the workshops, after having brought in a goods train, will follow the lines Q P Y K M.

The ways and turn-tables for loading and unloading the post-chaises are at X Y′.

The ways for housing passenger wagons are represented at D′ D″.

U′ U″ T′ and T″ are the ways for loading and unloading the goods wagons.

Plate 60.

Paris and Rouen Railway.—Stations at Mantes and Vernon.

References to the General Plan of the Station at Mantes (Seine-et-Oise), being the principal intermediate station on this line:—

A. Principal building, comprising the ticket and luggage-office, with lodgings above for the superintendent of the station.

B B^1 B^2. Sheds for the passengers to wait under.

C. *Café* and *restaurant.*

c. Represents a large counter, covered with fruit, pastry, and refreshments, which the passengers take standing, as the trains only wait about five minutes.

c^1 and c^2. Large cabinets.

c^3. Kitchen.

c^4. Wine and beer cellar.

D D′. Reservoirs for coal and water.

There is a steam engine of two horse power in the first, which pumps up the water from one of the wells, 15 metres deep, into a reservoir placed above. A pipe passes under the line, and establishes the equalism between the two reservoirs by leading off the surplus water from one to the other. One serves the trains coming from Paris, and the other those from Rouen. A trench is situated before each of these reservoirs.

d. Brick chimney of the steam engine.

E. Sheds for two locomotives and tenders.

F. Shed for five passenger carriages, which is too small, since there are always more than five carriages in reserve.

G. Shed for the goods depôt.

H. Stone bridge of three arches.

H^1. Brick bridge of one arch.

h^1. A steam engine stationed all the day on this line.

h^2. A crane, after the plan of M. Arnoux, is placed near this spot.

General Plan of Vernon Station (Eure):—

I. Principle building.

i. Ticket-office.

i^1. Second class waiting-room.

i^2. First ditto.

i^3. Luggage-office.

i^4. Lamp room and water-closet.

i^5. Water-closets for first-class passengers.

i^6. Public water-closets.

i^7. First-floor staircase, which is the lodging of the superintendent of the station.

i^8. Kitchen on the ground floor.

i^9. Large pent house, about three metres wide.

J. Building which serves for a lodging for the superintendent of the police.

J^1. Unoccupied space.

K. Engineers' office. These three buildings will be probably pulled down, as they project too much over the side of the street.

L L^1. Reservoirs of water. Two men are employed raising the water, which is only one metre deep, the same as at the station of Mantes, and all the others. One overflows into the other.

M. A shed for the storing of goods.

N. A quay, one metre above the level of the soil, for the depôt of goods.

P P^1. Small sheds to shelter the passengers in entering and descending from the carriages.

Q. House of the guard of the level crossing.

R. Level crossing.

Details of tank at D. The plan is taken at the height of the ground. This building is the type of all those built along the line. Although similar in design, some are built of stone, others of white flint, and lastly, of brick, which have received a coat of white paint. Some of these buildings are formed square, with an arch on each side, as at Vernon.

This reservoir is of cast iron, riveted together, 0^m 003 thick; it is 8^m long, 4^m 45 wide, 1^m 60 deep; its capacity is, therefore, about 57 cubit metres of water; the opposite sides are joined together by small bars of iron, as shown in the Figures. The spring of water which feeds it being at a great depth, a fixed engine is employed.

Plate 61.

Paris and Rouen Railway.—Station at Rouen for Passengers and Merchandise.

References to the Plan of the Station for Passengers and Merchandise at Rouen :—

The union of the way V with the way V^1 commences a little beyond the face of the shed. The way V^1 joins the way V^2. The luggage trains are arranged upon the way V^1, the wagons being brought as fast as they are loaded.

The way V^2 is that of departure. The passenger trains are arranged under the roofing, and depart along the points 5, 6, 4, and along the way V^2. The way V^2 is that of arrival. The trains stop before the platform T, where the officials collect the tickets obtained at Paris by the passengers, which they keep during the journey. During this time, the engineer detaches the engine from the train, runs it on for about 10 metres, and then again communicates with it by means of a long rope, with a common hook at the end, which is secured to the engine. A hook of another kind is fastened at the other end of the cord, which attaches to the first carriage, when the train is again put in motion to bring the carriages under the hall, and to allow of the passengers descending the quay *f*. The engine and train pass over the switch 3, and the engine over the switch 1; the instant the latter with its tender has passed, the switch 1 is changed to prevent the train and carriages passing along the same way. The draught is made for some time aslant nearly up to the switch 2, the engine being on the way

V^4, and the carriages on the way V^3; a man then draws a small cord, which is sufficient to detach the cord from the first carriage; upon which the train is left to itself, and the momentum carries it up to the station, where it is stopped by means of breaks.

The ways V^4 and V^5 are reserved ways.

The way V^6 is that employed to convey the luggage under the crane, and where the trains are changed.

The ways V^7 V^8 V^9 V^{10} and V^{11} are those on which the wagons are loaded.

The four ways V^{12} are ways to the sheds for goods, trucks, fish, &c.

The entry to the station at the side of departure line is formed by a handsome railing, 3 metres high, of cast and wrought iron, raised on a foundation of stone, 0^m 50 high at each end. A large gate A^1 A^2, four metres wide, the hinges of which are supported by square stone pillars, nearly the same height as the iron railing, and 0^m 70 square.

a^3 and a^4. Small wooden watch-houses for the porters, of an octagonal shape, and 2^m diameter.

a^5. Building for the guards.

a^6. Entry court for passengers and luggage, and for unloading goods arriving from Paris.

a^7. Fencing.

a^8. Gate at which goods are loaded on small cars, in the middle of the front.

The five gates with circular imposts admit passengers and luggage into the great vestibule B, conducting to the ticket and register office.

b^1. Passengers' ticket-office.

b^2. Office for passengers' luggage.

b^3. Office for luggage and effects, as goods required to be conveyed at great speed by the express trains.

b^4. Large space in which packages, trunks, &c., are deposited, directed, weighed, &c.

b^5. Closet, furnished with shelves, on which any property lost on the line is arranged.

b^6. Particular chamber for the receiver who superintends the delivery of the tickets.

b^7. Office for the superintendent of police.

b^8 and b^9. Square places, the gates of which communicate with the vestibule; when the luggage, effects, &c., are weighed and numbered, they are placed in small carriages, or chariots without springs, mounted on four wheels of 0^m 30

diameter, with limbers and pole, supporting a wooden body 1^m to 2^m wide, 0^m 70 high. Upon these cars being filled, they are drawn up to the luggage vans.

The Orleans Company was the first to employ these cars, but they were supported by three wheels, or rather rollers, of 0^m 10 in diameter; one of these is moved by a pole fixed vertically, the head forming a T for the purpose of directing it; the body is a large basket nearly 1^m 30 long, 0^m 80 wide, and 0^m 60 high.

They use cars on the St. Germains and Versailles lines (right bank), with rollers, like those of the Orleans, and an open body, of the same shape as those of the Rouen; but since there is little luggage on these two lines, they do not empty the cars, as upon the Orleans line, but place them in the luggage vans, and take them on with the trains.

c. Large counter, covered with all kinds of meats and liquors.

c^1. Entrance to the three waiting rooms.

c^2. First-class waiting room.

c^3. Second-class waiting room.

c^4. Third-class waiting room.

c^5. Large chimney.

There are two round tables covered with cloth, and some easy chairs, in the first-class wa ting room. The three waiting rooms are furnished with stuffed benches; and are separated by a neat open-work 1^m 80 high.

d. Water-closets for the first-class.

d^1. Water-closets for the second-class.

The construction of this building having been entrusted to English workmen, has received that attention to comfort for which they are so much celebrated; they are numerous, large, airy, and neat; each closet has an area of 1^m 50. They usually make three closets in the same space in France.

d^2 and d^3. Urinals and water-closets for those employed at the station.

e. Office for the superintendent of the station of the traffic.

e^1. Office of the engineer charged with the maintenance for the Rouen branch.

e^2. Water-closets for this office.

e^3. This was originally the office of the general magazine.

e^4. The magazine; but it has been removed to Sotteville. (See Plate 62, of the repairing workshop at Sotteville.)

e^5. Balance bridge.

f. Quay of departure.

f^1. Quay of arrival. These quays are only raised 0^m 40 above the rails; they have a stone kerb.

These quays are paved with wooden blocks, cut on the Lisle system. The platforms are watered at least once a day; this precaution is to prevent the wood, which is sheltered from the wet, being affected from continual drought.

f^2. Crane to raise the *Royal Messageries* or *Caillard* from their limbers, and to place them on wagon frames made expressly to receive them, after M. Arnoux's plan. (See Plate 50, "Third Series of Railway Practice.")

f^3. Office of the superintendents of the tolls at Rouen.

f^4. Chamber where the luggage is deposited, agreeing with the numbers answering to those given to the passengers leaving it; they are afterwards called in order, and given up.

f^5. Gate for the departure of passengers.

The quay f^1, which appears divided in half, by the way communicating with the turn-tables, is generally covered by two trap doors, with hinges, 4^m long to 0^m 50 wide, which are put down directly the wagons have passed over it.

The expresses arriving from Havre, Dieppe, &c., which enter by the gate h^5, are placed under the crane at f^6; they change their frames and convey them along the way T^2, by means of turn-tables, up to the point I—that is to say, to the end of the train.

This transverse way serves to bring the parcels.

g. Office for two officials employed in the goods department, and for an officer of customs, who has several subalterns with him, to inspect the goods. All the trucks arriving from Paris and the other stations are unloaded in this large saloon.

g^1. Lamp room.

g^2. Head porter's office.

g^3. Chimney, like that of the waiting rooms, marked c^5, which is arranged like those of close stoves. (See Figures.)

g^4. Cashier's office, accountant of the station.

g^5. Office of the chief superintendent of the station and of the traffic, and all other officials under his orders.

g^6. Private water-closets.

h. Court of departure for passengers and luggage, and for the arrival of fish-carts. Several omnibuses, hackney-coaches, and cabs, stand in this court, near the gate f^5.

h^1. A small wooden shed, on which slight repairs to the carriages are carried on.

h^2. Shed for the royal expresses and general stores. The depôt is filled with

a great number of wheels, poles, and several other pieces, as a reserve for these two classes of traffic.

h^3. Stables for horses employed on the railway in carting the luggage.

h^4. Lodgings for the grooms, and office of the expresses.

h^5. Gate opening on to the street of the Seine, conducting to the quay.

h^6. Porter.

i. Balance bridge, to weigh the loaded goods trucks, at the time of departure.

k, *k^1* and *k^2*. Sheds to shelter the goods, which have nothing particular in their construction. These sheds are built on the quay, raised 1^m20 above the rails.

l and *l^1*. Cranes to load the wagons, which are each furnished with a winch and axle, and have this peculiarity: instead of being moved by a handle in the ordinary manner, an endless chain is used, which passes over a pulley, with a neck which carries a pinion, &c.

l^2. The vehicles, such as carts and trucks, which bring the luggage, enter by this gate.

l^3. Office for the carting. The railway company contracts, at Paris and Rouen, with the contractors of transport, to undertake the carting at these two towns.

l^4. Wagon-office, where the weigh-bills of the wagoners are received, audited, and paid, and the charges regulated.

l^5. Small staircase to descend to the quay.

Plate 62.

Paris and Rouen Railway.—Goods Station at Batignolles, and Repairing Workshops at Sotteville.

Reference to the Plan of the Goods Station at Batignolles, situate about 2 kilometres' distance from Paris:—

a a a a. Great gate, 6 metres wide, for the arrival and departure of goods.

a^1 a^2 a^3. Paved courts.

b. Office of the superintendent of the station; office for booking goods, and for the weigh-bills.

b^1. Small office for the carman.

b^2. Ticket-office and waiting-room for passengers by the slow trains.

b^3. Platform for passengers.

b^4. Office of the superintendent of the working, and of the different officials employed in the goods department, situated on the ground floor. The first floor is similarly divided, and occupied by lodgings.

c. Shed to receive the goods intended for Rouen; the carriages arranged in the part c^1 and c^2 are unloaded on the platform c^3 and c^4, which is raised 1^m20 above the rails. The rolling gates placed between the posts are opened for this purpose; they completely close the shed when necessary. (See the gate *c c*.) When they desire to load goods, they bring the wagons upon the middle, or lateral way, and forward them, by means of turn-tables, to the way V, which is that of the departure.

d. Sheds receiving the arrivals, which are also raised about 1^m20 above the rails. They unload the wagons on the ways d^1 d^2 d^3 and d^4, and the loading of the wagons takes place at the sides d^5 and d^6; this latter forms an inclined plane.

d^7. Reservoir of water, containing about 20 cubit metres, supported upon four stone pillars, and fed by large wells bored between the pillars.

e. Shed for locomotives at the Paris station, with pits for cleaning the engines.

e^1. Lodging of the superintendent of the workshop.

e^2. Office.

e^3 and e^4. Smiths and machinists' workshops, &c.

e^5. Small steam engine for raising water into a reservoir placed above, for feeding the tenders.

f. Workshop for the repairs of passenger carriages.

f^1. Clock face 1 metre in diameter, placed in the middle of the length of the building.

f^2. Shed for passenger carriages.

Slight repairs only are carried on in these workshops.

f^3. Lower way, running in a direction perpendicularly to the others, on which a chariot (slide-table), serving to transport the wagons, moves so as to face the different ways.

f^4. Water-closets.

f^5. Switch-man's watch-box.

Line, followed by a goods train, starting from the point V at the station, in order to take the Rouen line.

A train starting from the point V follows this way, till it reaches the switch No. 2; then the head of the train continues along the way V^4, which is not more than 200 metres, until the last carriage has passed this switch, the train then

stops, and backs along the switch No. 2, the direction of which has been changed. It then passes along the way V^4 up to the switch No. 3, which, upon being passed, is shifted; it once more moves ahead, follows the line V^6 up to the switch No. 4, which, being turned in the right direction, causes the train to pass over the other, No. 5; and lastly, permits it to follow the way V^6, which is that of the departure from Paris for the three railroads of St. Germains, Versailles, and Rouen. The way V^1 serves for the arrival of the goods trains.

The way V^2 is an accommodation way, leading to the sheds.

The ways V^3 are those leading to the workshop.

The way V^4 is a small accessory way.

The way V^5 is that on which the train from St. Germains and Rouen arrives.

The way V^7 is the arrival line from Versailles and St.Cloud.

The ways V^8 and V^9 are used for the service of the workshops of St. Germains and Versailles.

In the principal elevation of the building marked B, all the doors on the ground floor are entrances to the offices. The first floor is occupied in lodgings.

The elevation of the office of the superintendent of the station is to be annexed to the building last described. The small pavilion appears on the outside to be constructed entirely of planks, tarred; they are 0^m 27 thick, and 0^m 20 wide, and the interior is furnished with plastering 628 centimetres thick, as well as the ceiling.

Plan of Sotteville Station, situated two kilometres from Rouen:—

The large workshops for performing extensive repairs of engines and carriages are placed at this station; they are under the *surveillance* and immediate direction of an English firm (Allcard and Buddicom), who are known to be entrusted with the construction and maintenance of the materials, and to whom these belong. The Rouen Railway Company merely occupies them for the time, and five years' notice is required of the manufacturers in the event of their declining to continue the execution of the agreement. The conductors of the trains are specially charged to take a memorandum of the distance passed over by each carriage, which is paid for according to an agreement previously entered into.

g. Central magazine of everything necessary for the working of the line.

g^1. Office of the guard of the magazine.

There is a large space which is entirely unoccupied, where it is talked of establishing new workshops for the Havre line.

h. Building with iron floors. (See the elevation.)

h^1. Vestibule.

h^2. Cellar.

h^3. Niches for books, constructed of stone.

The shelves which support the registers consist of bands of flat iron covered with list. A small lamp is always hung up to the ceiling, and burns by means of a current of air coming from the upper part, in the form of a ventilator. We see by the plan that the cavern is underground; it is shut by an iron door, and is then separated from the building by an antechamber.

h^4 and h^5. Water-closets.

h^6. Wood-house.

h^7. Account office.

h^8. Apartment of MM. Allcard, Buddicom, and Co.

h^9. Office where an account of the times is kept, including the time employed in every description of work; hence called the Time-keeping Office.

h^{10}. Porter's lodge.

h^{11}. Stair-case at the first landing. On the first floor is the clerks' office, and the draughtsman room for those employed by M. Buddicom. The lodgings are situated on the second floor.

i. Carpenter's workshop for the wagons; the line next the wall shows a number of wooden benches fixed to the wall. The two middle lines indicate a way on which the wagons are brought to be repaired.

j. Workshop of the metal turners.

k. Smith's workshop. There are twenty-four of these, built of brick. (See the Figures.) We may distinguish those with cast-iron caps, suspended by three iron rods, which lead the smoke into the chimney. They are represented as being furnished with bellows, but air will soon be procured by an ordinary ventilator.

k. Large chimney, of about 20 metres, for creating a draught to a furnace supplying steam to a fixed engine, which communicates the motion in all the workshops by means of *lying* shafts i^1, j^1, k^2, l, and l^1.

k^3. Position of two steam boilers and furnace, one serving as a substitute for the other. There is a large reservoir of water above, containing about 50 cubic metres.

k^4. Position of the steam engine.

k^5. Space unoccupied.

l. Adjusting workshop, which is not yet properly fitted up, but they place in it engines to mount, mortice, polish, and plane, &c., &c.

m. Warehouse for the iron and other metals employed in repairs.

m^1. Chest for iron.

n. Large shed for passenger wagons, capable of housing sixty. A painter's workshop is placed at the top of this shed, which is arranged for this purpose. There is a pit before this shed with a slide-table to communicate with each of the ways.

n^1. Water-closets for the workmen.

o. Workshops for extensive repairs to engines.

o^1 and o^2. Two pits, the whole length of the workshop.

o^3. Pit with a slide-table used to bring engines before each of the other ways.

p. Building serving to shelter the engines, and at the same time as workshops for small repairs; there are vices established at the side *p*, and along the entire length of the chamber.

p^1. Chamber for mechanics.

p^2. Small office for the coke accountant.

p^3. Coke depôt for the supply of the engines in use.

q. Shed for fire engines, &c.

r. Large level space of 2 metres, opposite the rails, on which six coke ovens are placed, all of which communicate with the same chimney by means of pipes.

r^1. Each oven has two doors opposite one another, and is filled with a large shovel, of about 30 decimetres of surface, which is worked by means of a small winch, as we see by the dotted semi-circle and interior lines. The ovens are served, two by two, by a small crane. The doors, which are formed of cast iron, are opened by means of a counterpoise. The line forming two portions of the circumference, and the two parallel lines surrounding these ovens, indicate a part of the ground paved with bricks; and the small squares at the extremity of each furnace represent cast-iron plates which are about one metre in area.

The way V is that of trains going to Paris.

The way V^1 that of trains going to Rouen. The engine, after having brought the train to the station at Rouen, returns (with the tender first) to that of Sotteville, where the switch No. 4 causes it to enter.

The way V^3 as far as the turn-table p^4. The tender is turned, and brought to the end of the way V^4. The engine proceeding along into building *p*, the tender is replaced on the turn-table, turned round, and brought upon the way V^3; the engine is next turned round, and attached to the tender, supplied with coal and water, and is once more ready for departure. When there are several engines in use, they are placed on the way V^5, or at the end of the way V^6.

The way V^2 is the line of traffic.

The elevation parallel to the way of the workshop for slight repairs of en-

gines in use serves also to house them. It is built of bricks, with a stone base; it is glazed up to a certain height; it is only enclosed with fixed blinds on the top; also the great quantity of steam and smoke escaping from the engines renders it necessary to keep this building very airy.

The large gates in the end elevation open in two portions upwards, by means of a small winch; one of these is represented open. The small gate serves for the workmen.

We still see the gates in the transverse section. There is a pit between each way throughout the whole length of the building.

Building in which the extensive repairs of the engines are executed:—A very small door for the passage of the workmen is made in each of the two gates at the ends of the façade; but these gates, being only 1 metre high above the threshold, are found so low, that the men are obliged to bend in order to pass through. There are two similar gates on the opposite side, but they are made sufficiently large.

This building is lofty; it is formed entirely of brick, with a slate roof, on wooden framing.

Water-closets:—There is planking situated opposite the door, which prevents the interior being seen. The middle is divided by a low brick partition, also a platform, and another portion of the partition descends at each side, which is united to the first obliquely, in order to prevent any one getting upon the seat with their feet.

The six coke ovens:—We may easily distinguish the gates, the counterpoise, and the small cranes in this figure. The horizontal lines, which pass over the ovens, indicate the iron circles, being 0·12 wide to 0·01 in thickness, in order to prevent the effects of expansion. The openings between each oven are supported by arches.

The workshops and buildings marked *h i j k l* in the plan, are glazed throughout their length; some of the windows are arranged in *vasistas*. The part where the forges are situated is raised for the purposes of ventilation, the openings of which are filled in with fixed blinds.

In the portion of the longitudinal section taken along the axis of the workshop, the covering is removed from one of the forges to show the pipes for catching the smoke. The first opening under each blast is made so as to allow the nozzle of the pipe of the ventilator to pass, and the second, which is beneath the pipe, is that of the ash-hole. We can easily perceive that one chimney unites four forges.

The coke depôt, which supplies the machines marked p^3 in the plan, is

divided in the direction of its length into nine galleries, or passages, by partitions a "*claire-voir*;" benches are raised to the right and left of these passages, on which sacks full of coke are arranged; each bench contains only one sack in front. The width of each passage is 60 centimetres; that of each bench 0·40. The eighteen benches are capable of holding altogether 270 full sacks.

The floor of this building is at the same height as that of the engines.

In the section taken through the axis of one of these passages, and along the line *a b* on the plan, the engines approach this depôt by the opposite side of the staircase—that is to say, at the side *a*.

Plate 63.

The Derby Station, at the Junction of the London and Derby, Birmingham and Derby, and Leeds and Derby Railways.

A. Buildings for the ticket office and waiting rooms.

B. Place for removing post-chaises or special carriages passing from Derby to Leeds.

B′. Place for forwarding post-chaises or special vehicles.

B″. Ditto, for taking on post-chaises or special carriages going from Derby to London or Birmingham.

B‴. Place for removing post-chaises or other special carriages passing from London or Birmingham.

C. Building for the goods traffic.

C′. Goods office.

D. Large rotunda for housing the engines.

E Workshops for repairing engines, with two stories.

E. Workshops for the repair of carriages.

F. Forges.

F′ F″. Forges and furnaces for the re-heating the tires of the wheels.

F‴. Pay office.

G. Offices.

G′. Entrance.

G″. Depôt.

G‴ and G⁗. Entrance for engines.

H and H′. Sheds for carriages.

H″. Building of two stories, to house and paint the carriages.

H″. Workshops for building carriages.

I. Shed for carriages.

I′. Shed for engines.

K. Small office.

L. Coke depôt.

Q. Reservoir.

R and R′. Sheds.

R″. Shed.

a' a'' a'''. Hydraulic cranes.

δ. Platform.

ϕ ϕ' ϕ''. Trenches.

γ γ' γ''. Sentry Boxes.

λ λ' λ''. Weighing machines.

The platforms for collecting the tickets are at a and a', at the side of the ways, and at the two corners of the plate.

T. Departure platforms for Leeds, London, and Birmingham.

V′. Ways of arrival for passengers. The trains pass along the way of departure by means of changing places or turn-tables.

T″. Arrival platform for passengers coming from the south (London), or the west (Birmingham).

V^3 V^4 V^5 V^6. Ways for the sheds.

V^7. Way for the arrival of goods.

V^8. Way for the departure of goods.

V^9. Way for the coal-wagons to the sheds.

V^{10}. Way of departure for the loaded coal wagons.

V^{11}. Way of arrival.

V^{12}. Way for the tenders.

V^{13}. Way for the engines.

V^{14}. Way for coke wagons.

V^{15} V^{21}. Ways for the sheds.

V^{21} and V^{28}. Ways for goods.

All the ways not pointed out by the letters are ways to the sheds or for the use of traffic, which may be easily seen from a mere inspection of the plate.

References to the Plan of the Foundations of the Building of the Waiting Rooms:—

a a' a'' a'''. Coal depôts.

b b'. Arched gallery.

c. Kitchen.

c'. Pantry.

e and *f*. Passage and landing on the stair-case.

d. Wood-house.

Ground Plan:—

a. Vestibule.

b. Ticket office.

c. Refreshment room.

d. Staircase leading to the first floor.

f. Ladies' waiting room.

g. Apartment of the guards.

h and *h'*. Water-closets and urinals.

Plan on the Level of the First Floor:—

a. Open portion above the vestibule.

a' a' a' a'. Gallery round the opening *a*.

b. Landing on the staircase.

e. Antechamber and office of the direction.

f and *g*. Commissioner's office.

c. Director's office, with closet.

d. Room for the meeting of the direction.

h and *h*. Corridor.

Plate 64.

The Great Western Railway Station at Bristol.

References to General Plan of the Station, taken at the Level of the Rails, at 6·00 metres above the ground of the courts of arrival and departure:—

a. Building containing the apartment of the director.

b. Entrance to the court of departure.

c. Entrance to the court of arrival.

d. Gentlemen's waiting-room.

e. Ladies' waiting room and water-closets.

f. Departure platform.

f'. Arrival platform.

g. Opening, through which the parcels and small packages are raised from the office to the platform.

h. First-class staircase, by which the passengers ascend from the office to the platform.

i. Second-class staircase.

g'. Opening, through which the small passages descend from the platform to the peristyle of arrival, placed under it.

k. Arrival staircase for first-class passengers, leading from the platform to the arrival portico, or peristyle.

l. Arrival staircase for second-class passengers.

All the anterior part of the station, from *v v* to the building at the head, is a shed for wagons.

o o. Slide-table, to remove wagons off one way to another.

p. Place for taking post-chaises or horses on and off.

p^1. Inclined plane.

q. Shed.

r. Goods depôt.

r'. Projected depôt. The site of the depôt is 6·00 metres lower than that of the line.

s. Building containing an engine to raise the goods trucks from the level of the depôts to that of the line. (See End elevation.)

The goods arrive in this building by the courts *t t*, which are *en suite* with the court of departure for passengers.

The ways $y\ y^1\ y^2\ y^3\ y^4\ y^5$ are reserved exclusively for the goods traffic.

The ways $\lambda''\ \lambda'''$ lead to workshops situated about a quarter of a league from the station. Sheds for the engines, reservoirs of water, and depôts of coke, are placed near these workshops, for supplying the engines every night when the traffic is over; the engines are placed in the sheds.

The other ways are intended for the use of passengers. All the other ways, excepting those of departure and arrival, (which pass along the platforms, being prolonged at λ and λ',) are ways to the sheds.

The entire portion of the ways $y^3\ y^4$ and y^5, between $a'\ b'$ and $a''\ b''$ is fixed on the level of the depôt. The small part $a'\ b'$, up to $a\ b$, is fixed on two moveable plates, which are sometimes arranged on the level of the site of the depôt, and sometimes on the same level as the line.

The prolonged ways $y^3\ y^4$ and y^5 are fixed near $a\ b$, at the side of the passenger station, and are on the same level as the ways of arrival and departure.

The small and large turn-tables are used for connecting the ways of the depôt with those for passengers, or, rather, form a communication with the ways for taking on the post-chaises and vehicles with those of the line to Exeter.

z. Superintendent of the station's office.

Plan taken on the Level of the Ground of the Courts of Arrival and Departure:—

a. Director's apartment.

b. Entrance for carriages into the court of departure.

c. Entrance for carriages into the court of arrival.

d d. Court of departure.

e e. Court of arrival.

f f f. Ticket office.

g. Entrance for porters with luggage.

h. Entrance for first-class passengers.

i. Entrance for second-class passengers.

k. Vestibule and staircase for first-class passengers.

l. Vestibule and staircase for second-class passengers.

m. Offices of the administration.

n. Ticket offices of the Gloucester line.

o. Dependencies of this office.

p and *q*. Vaulted passage, communicating with the courts of departure and that of the traffic.

r r r. Vaults under the line.

s s′ s″. Vaults intended for divers purposes: factors, men taking care of the lamps, carpenters. These vaults are underneath the carriage sheds *v o*, in general plan.

t. Portico underneath the arrival platform.

u. Staircase by which the first-class passengers descend beneath the portico.

v. Staircase for second-class passengers.

x. Parcel office.

y. Opening through which the parcels are carried down.

z. Urinals.

Elevation of the Buildings at the side of the Court of Departure:—

a. Entrance for luggage.

b. Entrance for first-class passengers.

c. Entrance for second-class ditto.

d. Entrance to the offices of the administration.

e. Entrance to the ticket-office of the Gloucester line.

f and *g*. Covered passages, leading from the court of departure to that of arrival.

Elevation next the Court of Arrival:—

The portico under the arrival platform extends from *a* to *b*.

c and *d* are covered passages.

Section along the line A B of the Roofing covering the Platforms and Ways:—

The pillars (*c c*), the transverse beams (*a b*) and (*a′ b′*), and the uprights (*a′ d b′ d*), as well as the parallel uprights, are not to be found in the plan A B on the general plan, but in the other one of the same figure, *v v* at the entrance to the sheds. The part above *a b*, is a kind of magazine which does not extend beyond the sheds.

Plan of the Building *r* for Goods:—

a. Covered space where the trucks run which bring the goods required to be transported from outside the station to the railway.

a′. Covered space where the trucks run that transport the goods that have arrived by the railway.

b. Departure platform for goods.

b′. Arrival platform for ditto.

a. a. Small cranes placed on the platform for moving the goods.

c′. Departure line.

c′. Arrival line.

c″. Line to the sheds.

d. Plate for raising the loaded wagons which are intended for departure.

d′. Plate for letting down the loaded wagons which have arrived at the depôt.

e. Steam engine to raise the loaded wagons to the level of the railway.

f. Office.

g. Booking office for goods going out.

g′. Booking office for goods coming in.

Transverse Section, along the Line A B, of Building *r*:—

r. The trusses are formed of wood and iron. The rafters and the struts, *a b*, and *c d*, are of wood, and all the other parts are formed of rod iron.

Longitudinal Section of the Roofs along the Line C D:—

The transverse trusses, the sections of which are represented n the last figures, are supported at every fourth column. The two intermediate trusses, between those supported on the columns, resting on longitudinal plates, which are

suspended between the pillars, to longitudinal trusses, as shown, whch cannot be seen from the inside of the magazine, excepting from the upper windows; *a a a* are points of support for the transverse trusses, which do not rest immediately on the pillars.

Plate 65.

Great Western Railway:—Details of the Swindon Station.

The Swindon station is situated about 77 miles from London, 41¼ miles from Bristol, and every train up and down stops there ten minutes.

The refreshment rooms are magnificent.

The large repairing workshops of this railway are situated at a short distance from this station.

References to the General Plan of the Station:—

A *a*. A building of two stories.

The waiting and refreshment rooms are on the ground floor, and the rooms for lodging the travellers on the first floor.

B *a*. A building perfectly similar in design.

There are platforms all round the buildings A and B, which are 5 metres (16 ft. 5 in.) on the longest side, and 3^m 50 (11 ft. 6 in.) at the ends.

V. Arrival line from Bristol.

V^1. Ditto, from London.

V^2 and V^3. Way for the use of goods.

V^4 Departure way.

V^5. Arrival ditto.

The remaining are accommodation ways.

C. Small ticket office.

Plan of the Refreshment Rooms to a Scale double that of the General Plan:—

A′ and B′. Compartments of refreshment rooms for second-class travellers.

A″ and B″. Ditto, ditto, for first-class, ditto.

F. Reserved space for the attendants, which is surrounded by a rectangular table next the side of the compartment A, and a semicircular one next that of A″.

There is a communication from F with the first floor by a private staircase.

The tables are always spread with different viands and refreshments.

The windows are glazed with large panes.

C C. Ladies' rooms for the first-class, with closets.

D D. Ladies' rooms of the second-class.

E E E E. Gentlemen's urinals.

End View of the Buildings:—

A and B. Buildings containing the refreshment and the chambers of the hotel.

We may perceive by this figure that the buildings are connected by a gallery passing over the ways on the level of the first floor.

P and N. Platforms for the accommodation of the Great Western Branch.

Q and R. Platforms for the accommodation of the principal line.

Transverse Section of the Station:—

A and B. Refreshment rooms.

S S. Chambers of the Hotel placed on each side of a corridor which runs throughout the whole length of the building.

Plate 66.

Railway Stations.—Stations of Eckington, on the Leeds and Derby, and those of Slough and Reading.

General Plan of the Eckington Station, on the Leeds and Derby Railway:—

A. Building of the ticket offices and waiting-rooms.

T T^1 Departure platform for Derby, and that of arrival from Leeds.

Q. Loading and unloading platform for coal and other goods.

V. Principal way from Leeds to Derby.

V^1. Ditto, Derby to Leeds.

V^2. Way by which the coals arrive from the mines in the neighbourhood.

V^3. Goods arrival line.

V^4 V^5 V^6 V^7 and V^8. Ways for shedding.

a. Vestibule.

b. Ticket office.

c. For the dependents.

d. Apartment of the guards.

e. Waiting-room.

f. Ditto, for ladies.

g. Water-closets.

h. Buildings, with steam-engine, reservoir, and hydraulic crane.

i. Shed to shelter passengers going on the Leeds side.

k. Hydraulic crane and pit upon the contiguous way.

General Plan of the Slough, or Windsor Station, upon the Great Western Railway:—

A. Buildings of offices and waiting-rooms for the departure of travellers who are going from London to Bristol.

A^1. Buildings, ditto, ditto, Bristol to London.

B and B^1. Waiting pavilion for her Majesty.

T. Departure platform for travellers going to Bristol, or that of arrival for travellers coming from London.

T^1. Departure platform for travellers going to London, or that of arrival for travellers coming from London.

C. Quay for entering and descending from the post-chaises.

E. Shed for the use of goods.

F. Switchmen's house.

V. Principal way from London to Bristol.

V^1. Ditto, from Bristol to London.

V^2. Arrival way for the travellers coming from Bristol.

The trains arriving from Bristol by the way V^1, pass, by means of changing places, upon the way V^2, setting down their travellers upon the platform T^1; they then go farther to retake the way V^1.

V^3. Arrival way for travellers coming from London upon the way V.

V^4 V^5 and V^6. Ways for the use of goods.

The goods leaving the Slough station are loaded under the shed E, upon the wagons placed upon the way V^6. The wagons will then go at will upon the way from London to Bristol by the changing ways *g*, or that of Bristol to London by the change of ways *r*.

V^4 and V^5. Ways serving to house the goods wagons to be added to the passenger train, or to set out singly. The goods trains going from London towards Bristol, station themselves before passing that of the passengers, in the part of *n* in *m*, and never pass the latter. Those which go from Bristol towards London, station themselves in the part of *o* in *p*.

U. Urinals.

a. Ticket office.

a^1. Entrance for first-class passengers.

a^2. Ditto, second-class, ditto.

b. Waiting-room.

c. Gentlemen's closets.

d. Ladies' waiting-room and closets.

e. Ticket offices.

f. Waiting room.

g. Ladies' room.

h. Ladies' closets.

i. Gentlemen's closets.

k. Parcels.

l and *m*. Station-master.

General Plan of the Reading Station of the Great Western Railway:—

A. Building of ticket-office for passengers going from London to Bristol.

A^1. Ditto, Bristol to London.

B and B^1. Goods Shed.

T. Departure platform for Bristol.

T^1. Ditto for London.

Q and Q^1. Quays for ascending and descending the post-chaises.

R. Locomotive shed.

S. Truck for transporting the wagons from one way to another parallel to it.

V. Principal way from London to Bristol.

V^1. Ditto, Bristol to London.

V^2. Arrival way for passenger trains coming from London and going to Bristol.

The trains leave the way V to pass upon the way V^2, by means of a changing-place *b*, and then go to retake this way V a little further on.

V^3. Arrival way for passenger trains coming from Bristol and going to London.

The goods trains station themselves to pass the passenger train of *m* in *n*, or from *o* in *p*, and never pass upon the side ways V^2 or V^3.

V^4 V^5 V^6 V^7. Ways for the use of goods.

V^8 V^9 V^{10} V^{11}. Ways for shedding.

a. Ticket-office for Bristol.

b. Waiting-room.

c. Goods office.

d. Ladies' room.

a^1. Ticket-office for London.

c^1. Waiting-room.

k. Refreshment-room.

l. Urinals.

The elevations of the buildings A and B are very similar to the elevations of the buildings, A^1 and B^1, on the the town side.

Plate 67.

Station at Huntsbank, at the Junction of the Manchester and Liverpool, and the Manchester and Leeds Railway.

A. Building of the offices and waiting-rooms.

T T^1. Departure platform for Liverpool.

T^2. Arrival ditto.

T^3. Ditto, Leeds.

V. Departure way for Liverpool or Leeds.

V^1. Arrival ditto.

V^2. Ditto, Leeds.

V^3 V^4 V^5 V^6 V^7 V^8. Service-way, and accommodation lines for the shedding.

R. Incline to arrive at the station, which is upon an embankment.

O. Street.

P. Inclined plane traversed by the locomotives.

a. Large refreshment-room, which is entered by two doors t t^1.

b f g and *l*. Ladies' closets.

c. Vestibule serving as waiting-rooms for travellers of the second and third classes going to Liverpool.

d. Offices communicating with the vestibules *c* and *e* by openings which serve for the distribution of tickets.

e. Vestibule serving as waiting-room for first-class travellers going to Liverpool.

m m. Gentlemen's urinals and closets.

n. Guards, inspectors, and lamp-room.

o. Audit-office.

h. Vestibule serving for waiting-rooms for first-class travellers going to Leeds.

k. Vestibule for second and third class travellers.

i. Ticket and parcel offices.

p. Porter.

q. Parcel depôt.

s. Station-master.

Detailed Elevation of the Station :—

A. Offices and waiting-rooms.

B. Bridge over street.

C. Ditto, canal.

Plate 68.

Manchester and Birmingham Railway.—Station at Manchester.

References to the General Plan of the Station :—

A *a*. Dwelling house.

B *a*. Building of two stories, containing the ticket offices and waiting-rooms on the ground floor, and offices of the directors on the first floor.

D. Street for the use of carriages and omnibuses taking the passengers to the railway.

S. Street, or waiting-court, for carriages and omnibuses which convey passengers from the railway.

T. Departure platform.

T^1. Arrival platform.

X. Court for loading and unloading *mail carts.*

Y. Shed.

E. Ways for the accommodation of goods. The warehouses are situated in the cellars under these ways, and under those for the accommodation of passengers.

a a. Opening by which the wagons descend to the depôts under the line, or are raised by an engine from the depôts to the station.

F. Court and ways forming the communication between the depôts.

a. Luggage office.

b, *c*. Chambers for the lamplighters, commissioners, and guards.

d. Corridor and staircase leading to the first floor.

e, *f*. Ladies' room, with water-closets.

h, *g*. Water-closets and urinals for gentlemen (first class).

i. First and second class waiting-rooms.

k. Ticket office for passengers for the Manchester and Birmingham line.

l. Waiting-room for the third class.

n. Water-closets ditto. The building is used for the service of Sheffield and Ashton-under-Lyne from this point up to *x*.

p o. Waiting-rooms for ladies travelling on the line (first class).

q r. Water-closets and urinals for first-class passengers.

s. Waiting-room for the first-class.

t. Ticket office.

u. Waiting-rooms for the second and third classes.

v. Water closets.

x. Staircase leading to the first floor and luggage office.

End Elevation and Longitudinal Section of the Building:—

H H H. Cellars serving for depôts, extending, as we see by the transverse section, along the whole length of the station, and placed between two streets in Manchester, one running by the side of the court F, and the other along a retaining wall on the side S.

H′ H′ H′ are three vaults appropriated for the steam-engine placed in the middle, which is employed to raise the wagons on the plates from the level of the magazine to the ways used for the goods. These three vaults are shown in the plan.

A machine like the former was established, during our stay at Manchester, near the end of the station. The building forming the waiting-rooms is formed of brick, excepting the heavy cornices, which are of stonework. A portico, consisting of cast-iron columns, runs along the front and sides of the building. Each depôt is divided lengthwise into three equal departments, that of the middle being occupied by a platform.

Transverse Section of the Station:—

B. Building for waiting-rooms and offices for the administration.

D. Street for carriages bringing passengers.

E. Goods depôt.

F. Court and ways serving the depôt.

H. Depôts.

T. Departure platform.

T′. Arrival ditto.

J. Waiting court for vehicles and omnibuses which convey the passengers from the station.

Plan of three Vaults H′ used for a Steam-engine:—

The engine is a recess at B.

a a are platforms suspended by cords for raising wagons to the ways used for goods, or for letting them down.

The wagons may be brought from any of the depôts, or placed in these depôts by the lateral ways shown in the figure, and by the transverse ways.

Plate 69.

South Eastern Railway.—Bricklayers' Arms Station.

References to the General Plan of the Station;—

A. Buildings of the offices and waiting-rooms, with portico.

A′. Waiting-room for post-chaise travellers.

A″. Lost luggage office. The reclaiming office is at the back of the court; the warehouse behind.

B. Departure court.

D. Lateral departure court.

E. Gate for carriages which bring travellers.

E′. Ditto, ditto, which carry them away.

D′. Arrival court, covered, and paved with wood.

C. Court paved with wood, inclined in a longitudinal direction. D C serving for loading post-chaises.

H. Houses inhabited by the *employés.*

T. Departure platform.

T′. Arrival ditto.

T″. Small platform upon which the officers walk to take the tickets; the trains stop before this platform before entering the departure station; the engine arriving at the head, then passes, by means of the changing-place K and K′ behind the train, and pushes it under the shed. It afterwards takes the changing-place and way V^{11}, upon the large turn-plate Z, where they turn it end to end, with its tender, without detaching the latter. It is then transported upon the way V^{11}, or upon the way V^{14}, before the building S, to be supplied with water and coke; it then returns and places itself upon the departure way V, at the head of a train about starting.

Y. Arrival for post-chaises.

R. Large shed for carriages.

R′. Locomotive shed.

S. Coke depôt and reservoir for feeding engines.

M. Warehouse for placing goods.

P. Court for goods.

Q. Place for cattle.

V. Departure way.

V^2 and V^3. Ways for housing passenger carriages.

V^4 Goods departure way.

V^5. Ditto, arrival, ditto.

V^6 and V^7. Accommodation ways for goods.

V^8 V^9 V^{10}. Accommodation ways for unloading carriages.

V^{11} V^{12} V^{13} V^{14}. Accommodation way for supplying and cleaning engines.

a. Portion of vestibule where they issue tickets to second-class passengers, who enter by the doors *p* or *p'*.

b. Portion of vestibule of the first-class who enter by the door *q*.

c. Waiting-room for second-class passengers.

d. Waiting-room for first-class ditto.

e. Ladies' waiting-room, second-class, and water-closets.

f. Ditto, waiting-room, first-class, ditto.

o o. Passage by which second-class passengers go to the platform without mixing with those of the first.

n. Passage establishing a communication between the peristyle and the platform; this passage serves principally for the removal of luggage.

j. Vestibule and third-class ticket office; these travellers wait in the vestibule.

h and *i.* Luggage office.

k and *l.* Ladies' waiting-room of the third-class.

m. Lamplighters.

n. Water closets.

r s t. Small wood and coal depôt.

a a a. Switchmen's watch-box.

γ γ. Beam for weighing goods.

T. C. Savill, Printer, 4, Chandos-street, Covent-garden.